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ABSTRACT

This text is intended to provide a basic understanding of selecting, maintaining, and managing farm machinery. The following topics are covered in the individual chapters: dealing with typical problems in farm machinery management; measuring machine capacity; improving field efficiency; matching machine size and capacity; estimating power requirements; estimating fixed costs; estimating fuel and lubricant costs; estimating repair costs; computing total costs for machines and operations; deciding when to trade; considering future capacity needs; calculating custom work costs; comparing ownership, leasing, and rental costs; and starting machinery management. The final chapter, which contains six case studies, deals with recordkeeping, the cost of new machinery, financial analysis, peer pressure, using a budget, and cash flow analysis. A chapter summary and set of quiz questions conclude each chapter. Answers to the questions are also provided. Appendixes include reference tables, calculator and computer sections, and a list of suggested readings. (MN)

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Machinery Management

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AUTHOR: *Wendell Bowers*, professor of agricultural engineering, Oklahoma State University, has authored books, numerous publications and educational materials on machinery management. Professor Bowers has specialized in machinery management for 26 of the 30 years he has been involved in agricultural engineering extension in both Illinois and Oklahoma.

CONSULTING EDITORS: *Roland F. Espenschied*, Ed.D., professor of Agricultural Engineering and Vocational Agriculture Service, University of Illinois, has written many publications and prepared other types of audiovisual materials in agricultural mechanization during his 32 years as a teacher and teacher-educator. Professor Espenschied has spent 22 years specializing in agricultural mechanics in the Agricultural Engineering Department of the University of Illinois following 10 years of teaching vocational agriculture.

Thomas A. Hoerner, Ph.D., is a professor and teacher-educator in agricultural mechanics at Iowa State University. Dr. Hoerner has 23 years of high school and university teaching experience. He has authored numerous manuals and instructional materials in the agricultural mechanics area.

Keith R. Carlson has eighteen years of experience as a high school vocational agriculture instructor. Mr. Carlson is the author of numerous instructor's guides, including the American Oil Company's "Vo-Ag Management Kits." Many of his aids have been available under the name Vo-Ag Visuals. All instructor's kits for the FMO texts are being prepared by Mr. Carlson.

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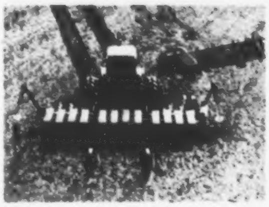

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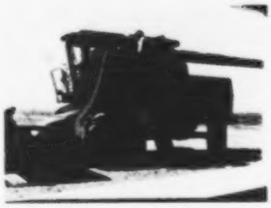

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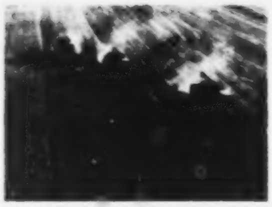

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Matching Machines and Power Units

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PREFACE

The ability to manage machinery is an important skill that must be mastered by farmers and ranchers who want to compete in our complex worldwide commodity marketplace. With the basic information in this book, you can build a solid foundation of knowledge that can be used to make the most efficient machinery management decisions and help keep your business competitive.

There is no substitute for personally solving a machinery management problem. You should not rely on the opinions or "short-cut" methods of others when you make decisions that affect your business. Using the complete up-to-date facts and formulas in this book, you can prepare yourself for the challenge of making machinery management decisions for your unique business situations.

The book is divided into three sections. The first section covers the topic of how to become more efficient by matching machines and horsepower to different situations. Section two gives information that can be used to analyze and estimate costs associated with keeping machines running on a daily basis. Section Three helps you answer the question of "Should I buy a new machine, or should I fix the one that I have?" It also gives information that can be used to plan for the efficient future use of machinery so that you can increase your business returns to their maximum potential.

Throughout this book, emphasis is placed on solving problems with a hand calculator. The procedure for solving problems with a hand calculator will be shown in the appendix for any problems throughout the book where the calculator symbol appears.

For those of you who have computers, the appendix also shows you how to set up computer programs for some of these example problems. Whether you use a hand-held calculator or a computer, you will be pleasantly surprised at the wide variety of management decisions that you can make once you master these example programs.

MATCHING MACHINES AND POWER UNITS

The first step in becoming a skilled machinery management decision-maker is to learn how to properly select and match power units. You must choose the most economical compliment of tractors and machinery that can achieve the desired results for each farm or ranch operation.

The first section consists of five chapters. This information will help you estimate:
- Machine capacity
- Field efficiency
- Power requirements

1

Introduction

Fig. 1—Modern Agricultural Machinery Must Be Skillfully Managed For Maximum Profits

INTRODUCTION

Machinery management has increased in importance in today's farming operations because of its direct relation to the success of management in mixing land, labor and capital to return a satisfactory profit (Fig. 1).

The importance of machinery in the total farming operation is indicated by the machinery costs in relation to the total costs. Typically, machinery costs overshadow all other costs except land (Fig. 2). Machinery costs may run as high as $100 per acre ($240 per hectare) each year with total new cost investment in machinery often exceeding $150 per acre ($370 per hectare). It is not unusual to find that differences in profit from one farm to the next are due solely to differences in the way machinery is selected and managed.

TYPICAL PROBLEMS

The many problems of machinery management are each quite varied in their nature. Following are some typical examples of the more important problems. In each case the decision could make a difference whether the farm returns to profit or loss.

- *How much equipment should be owned?*
- *What size equipment is needed?*
- *How often should you trade machinery?*
- *Repair present machine or trade?*
- *How can fuel costs be kept to a minimum?*

These are but five examples of the many important decisions related to owning and operating agriculture machinery.

HOW MUCH EQUIPMENT SHOULD BE OWNED?

Modern farming operations usually involve several different crops, with each one having its own tillage, planting and harvesting requirements. You could make up quite a list of special tools by size and type for each field operation. But each machine purchased means more overhead costs—depreciation, taxes, shelter, insurance and interest. These overhead costs, which can also be called fixed costs, eat up profits in a hurry if excessive.

Lack of adequate equipment may mean not getting crops planted or harvested on time. If key operations are delayed, yields may be reduced, or as some people say, "you have a timeliness loss."

Modern farming and ranching is a business. Like any business you must try to make a maximum return on your

Fig. 2—Only Land Costs Are Higher Than Machinery Costs

Fig. 3—Big Tractors Provide More Capacity, But Need Lots Of Use To Hold Down Costs

investment. Efficient selection and management of the equipment for your farm or ranch should help you achieve both short and long range financial goals.

WHAT SIZE OF MACHINE IS NEEDED?

Larger machines mean lower labor costs. Large tractors, for example, furnish plenty of power to complete big acreage jobs in a hurry (Fig. 3). But unless the tractor has a high annual use or you plan to own it for 10 to 12 years or more, overhead or fixed costs can exceed even the most expensive labor costs.

Smaller tractors cost less per hour than larger tractors. By having high annual usage, you may be ready to trade in three-to-five years instead of eight-to-ten years (Fig. 4). Smaller tractors have smaller capacity, which in turn, can cause delays in key field operations.

Fig. 4—Smaller Tractors Have Less Capacity, But May Have Lower Cost Per Hour

By carefully analyzing the work to be done in the available time, tractors can be selected to work with the correctly sized machines to complete important field operations on time. This timeliness factor makes proper machine size selection important.

HOW OFTEN SHOULD MACHINERY BE TRADED?

Frequent trading, in some cases, means always having the latest and best equipment (Fig. 5). Some call it "pride of ownership." Having new equipment generally reduces downtime and repairs, but may result in a higher cost per acre.

Some managers must trade machinery more often because they neglect their maintenance program. Trading often is nice if you can afford it, but remember, average costs may be higher. With good maintenance, most agricultural machines last eight-to-ten years or more, producing the lowest unit cost.

Fig. 5—Frequent Trading May Be More Expensive Than Long-Term Ownership, But Breakdowns Are Also Expensive

But older machines are more likely to have a higher percentage of downtime and can easily become obsolete. Repair costs also increase with the hours of use.

To know exactly when to trade a machine, it is important to know how to take into account these four elements:

1. *Average cost per unit of use*
2. *Cost to trade compared to making repairs*
3. *Reliability of the machine*
4. *Net effect on profit of total farming operation*

REPAIR PRESENT MACHINE OR TRADE?

The decision of whether you should repair the existing machine or trade for a new one may be difficult to make, unless you have an accurate estimate of how it will affect profits for the total farming operation. The age of the current machine and the history of the machine's reliability are important factors (Fig. 7).

If a machine has a recent history of breakdowns then it may have reached the end of its useful life. Owning machinery that is reliable and meets quality and performance needs in the field is one of the best ways to hold down the cost of production.

WHY STUDY MACHINERY MANAGEMENT?

This manual will provide the basic information that can be used to select and maintain farm machinery. Machinery management is a complex subject. You must be able to solve these difficult machinery management problems in order to help maximize returns.

If you are to receive maximum returns from an agricultural operation, then you must learn as much as possible about correct management of agricultural machinery. While you may never know if your decision was the best one, at least you should have eliminated costly mistakes.

Fig. 6 — For Some Situations Hiring A Custom Operator Costs Less Than Ownership

Dealer Guide To Used Equipment
Tractor Trade-In Guide

Fig. 7 — When to Trade or Repair is a Major Decision.

Why is it important to learn so much about machinery management? In the days of farming with horses and even when many farms had their first tractor, machinery related decisions were of less importance. The farms were small with few machines and most of the management methods were cut-and-dried.

No matter the size of the farm, it is difficult to maximize returns when commodity prices are low and input costs are high. While you may not have much control over prices, you can do something about input costs resulting from machine purchases and maintenance.

How can you become prepared for the increasing need for machinery management? Some suggestions are:

1. Learn how to use the management principles presented in this manual.

2. Keep complete records of field work done by various machines and the number of working days available for critical field operations (Fig. 8). By knowing the average capacity of machines and number of work days available, a more effective job of selecting machinery is possible.

3. Know how to accurately estimate costs for any machine and how to combine costs of machines to estimate total cost for an entire system. Many important decisions are based on costs.

4. Know how to improve equipment reliability — always work towards the elimination of unnecessary downtime.

5. Improve field efficiencies with machines to cut costs and complete more work in the available time (Fig. 9).

6. Develop short and long range plans for your farming operation, including the repair, purchase and trade-in of equipment.

7. Keep thinking of ways to improve the efficient ownership and management of agricultural machinery. It is unlikely a single decision will produce instant financial success. With the proper approach, however, you will learn how to arrive at a series of proper decisions that will increase net profit.

8. Review the problems with a calculator or a microcomputer to speed up management decisions. Problems throughout the book are presented a second time

Fig. 8—Complete And Accurate Records Pave The Way To More Profitable Decisions

Fig. 9—Look For Ways To Improve Machinery Efficiency

in the Appendix with calculator directions. These problems are marked with this symbol.

9. Throughout this book, paragraphs and formulas containing only metric terminology are noted by the symbol Ⓜ.

HOW CAN OPERATING COSTS BE KEPT TO A MINIMUM?

As you will see in the coming chapters, operating costs include labor, fuel, lubricants and repairs. In comparison to fixed costs such as depreciation, taxes, housing, insurance and interest, operating costs are usually lower. Operating costs, however, are something that you can control. This book will tell you how to estimate operating costs and what you can do to keep them to a minimum without reducing production.

Management tip: Reducing operating costs by 10-15 percent is a realistic goal that could help you save $5 an acre, or more.

Improper matching of tractors and implements can increase operating costs by as much as 15 to 20 percent. When you need to use big tractors at partial loading, gear up and throttle back to save as such as 50 percent on fuel consumption.

CHAPTER QUIZ

1. Which of the farming costs is the most likely to exceed costs for machinery?

2. Give three specific examples of machinery management decisions that affect profits.

3. Which tractor would have the highest percent of its annual costs as fixed costs? A large tractor used 400 hours a year or a small tractor used 800 hours a year?

4. How many years should most agricultural machinery last with proper care and maintenance if it has typical annual use and care?

5. What are three ways the average farm manager can improve his ability to make the proper machinery management decisions?

6. What is the machinery manager's goal when buying machinery?

7. What are the two alternatives available when deciding to buy machinery?

8. What are three things that can be done to hold down operating costs?

2

Measuring Machine Capacity

Fig. 1—Estimating Capacity Is Important In Order To Match Machine Size To Available Working Time

Fig. 2—Adequate Planting Capacity Is Important To Secure Maximum Yields

INTRODUCTION

The capacity of a machine is its rate of performance. Depending on the kind of machine, the performance or capacity will be measured in terms of acres per hour (hectares per hour), tons per hour (tons per hour), or hundredweight per hour (quintals per hour).

It is important for efficient farm managers to understand how to estimate capacities of machines they plan to buy for future use. It is important to know machine capacities for selection of power units and equipment that can complete important field operations on time. But, it is also important to avoid the added expenses of larger-than-necessary machines.

CAPACITY MEASURING METHODS

The capacity of a machine is its rate of performance, usually reported in terms of *quantity per time*. "Acres per hour" (hectares per hour) is the most common measure of machine performance. Harvesting and processing machine performances may be measured as bushels or tons per hour. Bushels, a rather inaccurate measure due to variations in moisture content and grain densities, has been replaced, in many cases by the hundredweight measure which is 100 pounds. In metric units the common units include kilograms; tons (1000 kg) or quintals (100 kg).

Capacity of harvesting machines, in some cases, requires measurements other than area per time.

Three possible methods of measuring machine capacity include:

- **Field capacity (acres or hectares per hour)**
- **Material capacity (hundredweight, cwt. or kilograms per hour)**
- **Throughput capacity (pounds or tons; kilograms or metric tons per hour)**

FIELD CAPACITY, usually expressed in *acres* (hectares) *per hour*, is the most commonly used measure of machine capacity.

MATERIAL CAPACITY, once commonly referred to in bushels, is now usually measured by *hundredweight (cwt.) (or kilograms) per hour.* In many cases, *tons per hour* is used. Material capacity is simply a measure of material, such as silage or grain, harvested by a machine. But, in the case of harvesting machines such as combines, this is not a completely accurate measure of capacity because it measures only the amount of grain or forage harvested. To measure *total* amount of material passing through the machine, *throughput capacity* is used.

THROUGHPUT CAPACITY is a special term used to compare machines, such as combines and potato harvesters, that separate undesirable material from the desirable material. In these cases, the *weight of the material handled* is the accurate capacity measure. Throughput, then, refers to the time rate of handling a total weight of material, usually in terms of *pounds (kilograms) per hour.* In the case of a combine, the pounds-per-hour (kilograms-per-hour) throughput would include grain, chaff, straw and any other material that enters the header. Because moisture affects the result, a moisture report should accompany the throughput capacity rating.

Let's consider a sample problem using these three different capacity measurements. It is determined that a combine with a 20-foot (6.1-meter)-wide header is combining wheat at a speed of 300 feet (92 meters) per minute. In a one minute time period, 1000 pounds (454 kilograms) of material enters the header. Of this amount, 500 pounds (227 kilograms) enters the grain tank and the remaining 500 pounds (227 kilograms) of material is discharged through the combine. See metric formulas on page 18, CAPACITIES IN METRIC.

Using the unit-factor method (color cancel marks) to arrive at the answer in proper units, machine capacities equal:

FIELD CAPACITY

Speed times width equals Field Capacity:

$$\frac{300\ \cancel{\text{feet}}}{\cancel{\text{minute}}} \times \frac{60\ \cancel{\text{minutes}}}{1\ \text{hour}} \times 20\ \cancel{\text{feet}} \times \frac{1\ \text{acre}}{43{,}560\ \cancel{\text{ft.}^2}}$$

Answer = 8.26 acres per hour

MATERIAL CAPACITY

Pounds (kilograms) harvested per hour:

$$\frac{500\ \cancel{\text{pounds}}}{\cancel{\text{minute}}} \times \frac{60\ \cancel{\text{minutes}}}{1\ \text{hour}} \times \frac{1\ \text{cwt.}}{100\ \cancel{\text{pounds}}}$$

Answer = 300 cwt. (or hundredweight) per hour

This answer could also be expressed in tons per hour:

$$\frac{300\ \cancel{\text{cwt.}}}{\text{hour}} \times \frac{100\ \cancel{\text{pounds}}}{1\ \cancel{\text{cwt.}}} \times \frac{1\ \text{ton}}{2000\ \cancel{\text{pounds}}}$$

Answer = 15 tons per hour

THROUGHPUT CAPACITY

Total amount of material per hour

$$\frac{1{,}000\ \text{lbs.}}{\cancel{\text{minute}}} \times \frac{60\ \cancel{\text{minutes}}}{1\ \text{hour}} = 60{,}000\ \text{pounds per hour}$$

$$= 30\ \text{tons per hour}$$

These examples are briefly covered here to familiarize you with the technical capacities. For most practical farm or ranch applications, acres per hour and tons per hour are the preferred ways of measuring capacity. Material capacity requires accurate measuring techniques and is easily affected by moisture, yields and other factors such as platform cutting height.

All of these capacities are theoretical capacities, not effective capacities. Effective capacity brings in the factor of *efficiency*. After reviewing practical methods of measuring machine capacity, the factor of efficiency will be introduced.

MACHINE CAPACITY

The units of measure of machine capacity used throughout the book will be:

- **Acres per hour (hectares per hour)**
- **Tons per hour (U.S. customary and metric)**

Learning to use these terms is important to proper management.

ACRES-PER-HOUR CAPACITY

Machine capacity, when measured in acres per hour

Fig. 3—Capacity Is Measured In Tons Per Hour For Some Machines

(hectares per hour), is determined by three factors:

- **Speed**
- **Width**
- **Efficiency**

SPEED is the average rate of travel expressed in miles per hour (mph) or kilometers per hour (km/h).

WIDTH is the distance in feet (meters) across the processing portion of the machine.

EFFICIENCY is the ratio of the effective capacity of a machine to its theoretical capacity. It is an indicator of how much time is spent working versus turning, filling hoppers and other jobs.

Fig. 4—There Is A Preferred Speed Range For Each Field Operation

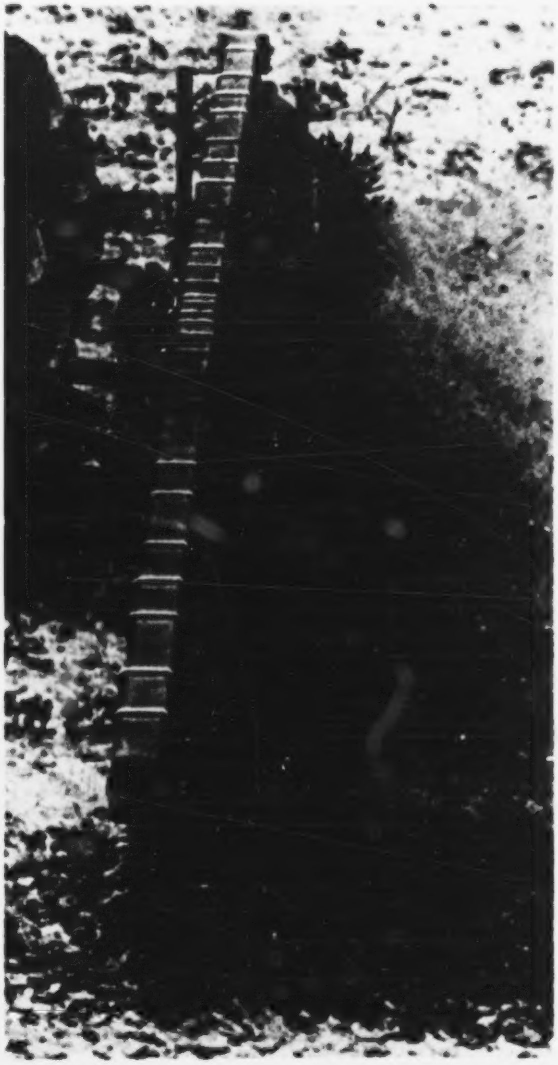


Fig. 5—In Some Cases, A Faster Speed Is Necessary To Make An Implement Work Properly

TONS-PER-HOUR CAPACITY

Capacity of a machine like a forage harvester or a silage blower is often expressed in tons per hour (Fig. 3). The only major difference is the use of tons as a unit of work accomplished instead of acres.

Let's take a closer look at each of the factors that determine capacity and learn how to make critical management decisions.

Fig. 6—A Precise Speed Is Needed To Insure Proper Application Rate In Spraying Operations

SELECTING THE BEST OPERATING SPEED

Most field machines work best at a given range of speed. A modern moldboard plow, as shown in Figure 4, functions best at a 4- to 6-miles-per-hour (6.4- to 10-kilometers-per-hour) speed. Going too slow in this case may cause the furrows to stand on edge and not break up the soil as desired. Going too fast may leave the field too smooth and waste power due to the added draft at higher speeds.

The speed may need to be quite slow for some operations, such as cultivating small row crops, to avoid damage to the plants. On the other hand, modern rotary hoes need to run fast to kick out weeds (Fig. 5). A rotary hoe operating at speeds from 6 to 10 miles per hour (9.6 to 16 kilometers per hour) is not unusual.

There are also operations, such as chopping heavy-yielding silage or combining high-yielding grain, where the density of the crop being harvested calls for extra power. In such cases, the extra power requirement usually limits speed.

MEASURING SPEED

It is a good idea to make an accurate speed check because speed indicators may be affected by tire size, field conditions and other factors.

Speed is measured in miles per hour (mph) or kilometers per hour (km/h). Some operations, like spraying, require a precise speed because the sprayer must be accurately calibrated (Fig. 6).

The procedure for making an accurate speed check is not difficult. Just determine how far the tractor or machine travels in a given period of time.

Suppose you check the speed for one minute and find the tractor traveled exactly 440 feet (135 meters). In one hour, a distance 60 times as far could be traveled because there are 60 minutes to an hour:

60 × 440 = 26,400 feet

Ⓜ 60 × 135 = 8100 meters

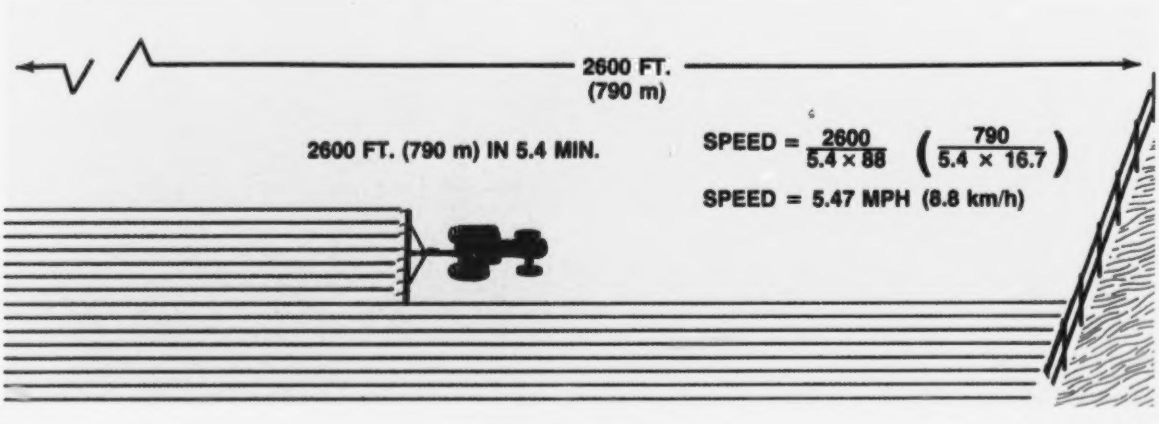

2600 FT.
(790 m)
2600 FT. (790 m) IN 5.4 MIN.
SPEED = $\frac{2600}{5.4 \times 88}$ $\left(\frac{790}{5.4 \times 16.7}\right)$
SPEED = 5.47 MPH (8.8 km/h)

Fig. 7—One Method Of Checking Speed When You Know The Field Length

Because there are 5,280 feet in one mile, the speed would be 26,400 divided by 5,280 or five miles per hour.

(There are 1000 meters in one kilometer. Divide 8100 by 1000 to obtain 8.1 kilometers per hour.)

There are two convenient methods or formulas for checking speed. The more accurate method is shown in Figure 7. Determine the exact length of the field (or distance traveled) and the time needed to travel the distance in minutes. The formula is as follows:

$$\text{Speed, mph} = \frac{\text{Distance, feet}}{\text{minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} \times \frac{1 \text{ mile}}{5280 \text{ feet}}$$

Numerically: $\frac{60}{5280} = \frac{1}{88}$

Ⓜ Speed, km/h

$$= \frac{\text{Distance, meters}}{\text{minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} \times \frac{1 \text{ kilometer}}{1000 \text{ meters}}$$

Numerically: $\frac{60}{1000} = \frac{1}{16.7}$

Then the equation for making a speed check is as follows:

$$\textbf{Speed, mph} = \frac{\textbf{distance, feet}}{\textbf{time, minutes} \times \textbf{88}}$$

Ⓜ $\text{Speed, km/h} = \frac{\text{Distance, meters}}{\text{time} \times 16.7}$

If, as shown in Figure 7, you drive 2,600 feet in 5.4 minutes, the speed would be calculated as follows:

$$\text{Speed, mph} = \frac{2600}{5.4 \times 88} = \frac{2600}{475.2} = 5.47 \text{ mph}$$

Ⓜ $\text{Speed, km/h} = \frac{790}{5.4 \times 16.7} = \frac{790}{90} = 8.8 \text{ km/h}$

An easier and simpler method of measuring speed is to mark off a distance of 88 feet (or 16.7 meters) in the field. Then, with a running start, check the number of seconds needed to drive between the markers using the rear axle on the tractor as a reference point (Fig. 8). The formula for calculating speed when using this method is:

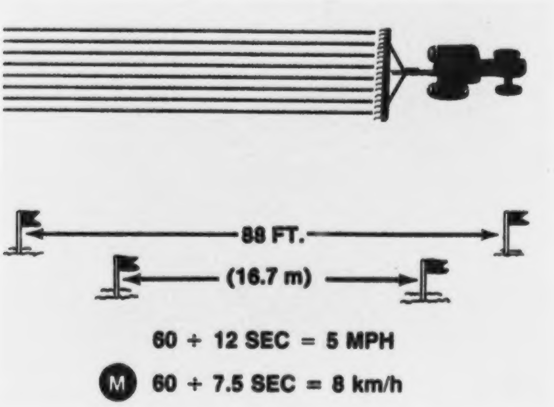
$$\textbf{Speed, mph} = \frac{\textbf{60}}{\textbf{seconds to travel 88 ft.}}$$

Ⓜ $\text{Speed, km/h} = \frac{60}{\text{seconds to travel 16.7 meters}}$

Let's try an example. It takes 11 seconds to drive 88 feet (7 seconds to drive 16.7 meters) with a self-propelled swather. What is the speed?

$$\text{Speed} = \frac{60}{11} = 5.45 \text{ mph}$$

Fig. 8—To Make A Simple But Accurate Speed Check, Divide 60 By The Time In Seconds To Travel 88 Feet (or 16.7 meters)



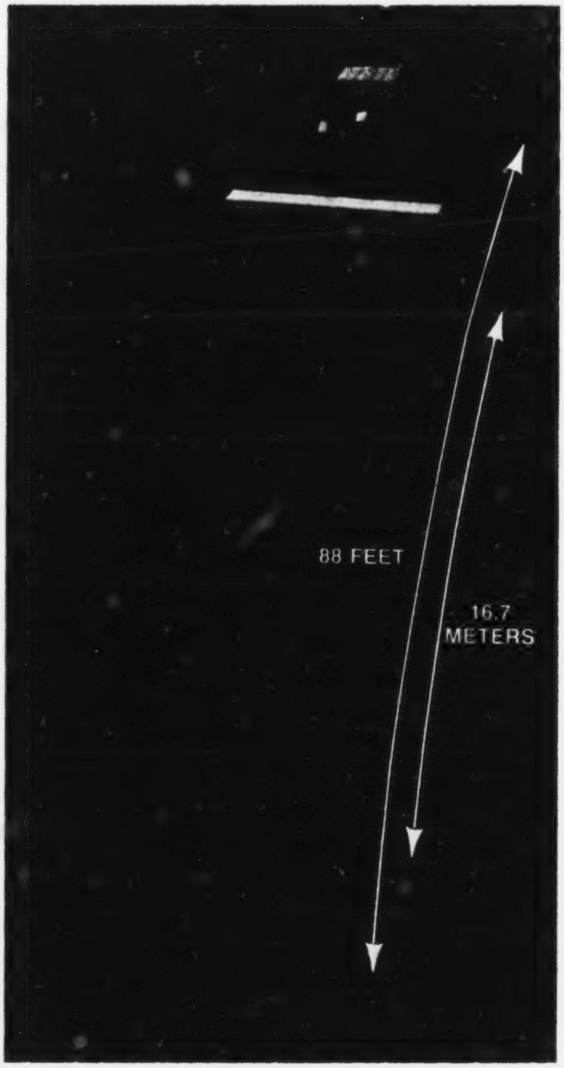


Fig. 9—To Plant At Five Miles Per Hour (8 km/h), Adjust The Speed Until You Drive 88 Feet In 12 Seconds (or 16.7 meters in 7.5 seconds)

TABLE 1
TIME-SPEED RELATIONS*

Time To Travel 88 Feet, Seconds	Speed, mph
3	20.0
4	15.0
5	12.0
6	10.0
7	8.6
8	7.5
9	6.7
10	6.0
11	5.5
12	5.0
13	4.6
14	4.3
15	4.0
16	3.8
18	3.3
20	3.0
24	2.5
28	2.1
32	1.9
36	1.7
40	1.5

*This table may also be used to relate Time to Travel 16.7 meters to Speed in kilometers per hour. The numbers and relationships remain the same.

Ⓜ Speed $= \frac{60}{7} = 8.6$ km/h

This method is also useful in adjusting the speed to a desired point. Suppose you want to operate a planter at a speed of exactly five miles per hour. The same method may be used except now divide 60 by the desired speed to get the time to travel 88 feet (or 16.7 meters) (Fig. 9):

$$\text{Required time (seconds)} = \frac{60}{\text{speed}}$$

Fig. 10—Modern Tractors Have A Wide Selection Of Speeds

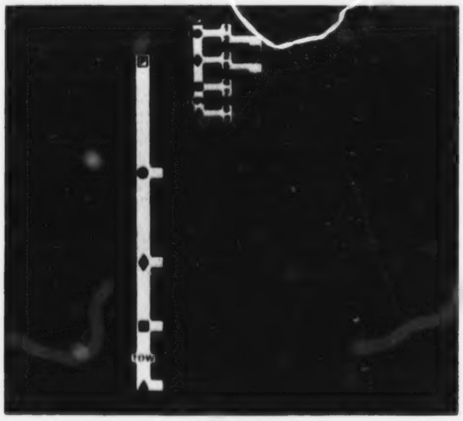


Fig. 11—Hydrostatic Drive Lets You Work At Best Speed For Various Field Conditions

For 5 mph, time $= \frac{60}{5}$ or 12 seconds.

Ⓜ For 8 km/h, time $= \frac{60}{8}$ or 7.5 seconds

Adjusting the speed to make the run of 88 feet in exactly 12 seconds (or 16.7 meters in 7.5 seconds) assures a planting speed of five miles per hour (8 km/h)

In order to allow operation of different types of equipment at the proper speed, manufacturers provide a wide range of field speeds. This is accomplished in two different ways. As shown in Figure 10, a multi-

Fig. 12—Unused Cutting Width Reduces Field Efficiency And Capacity

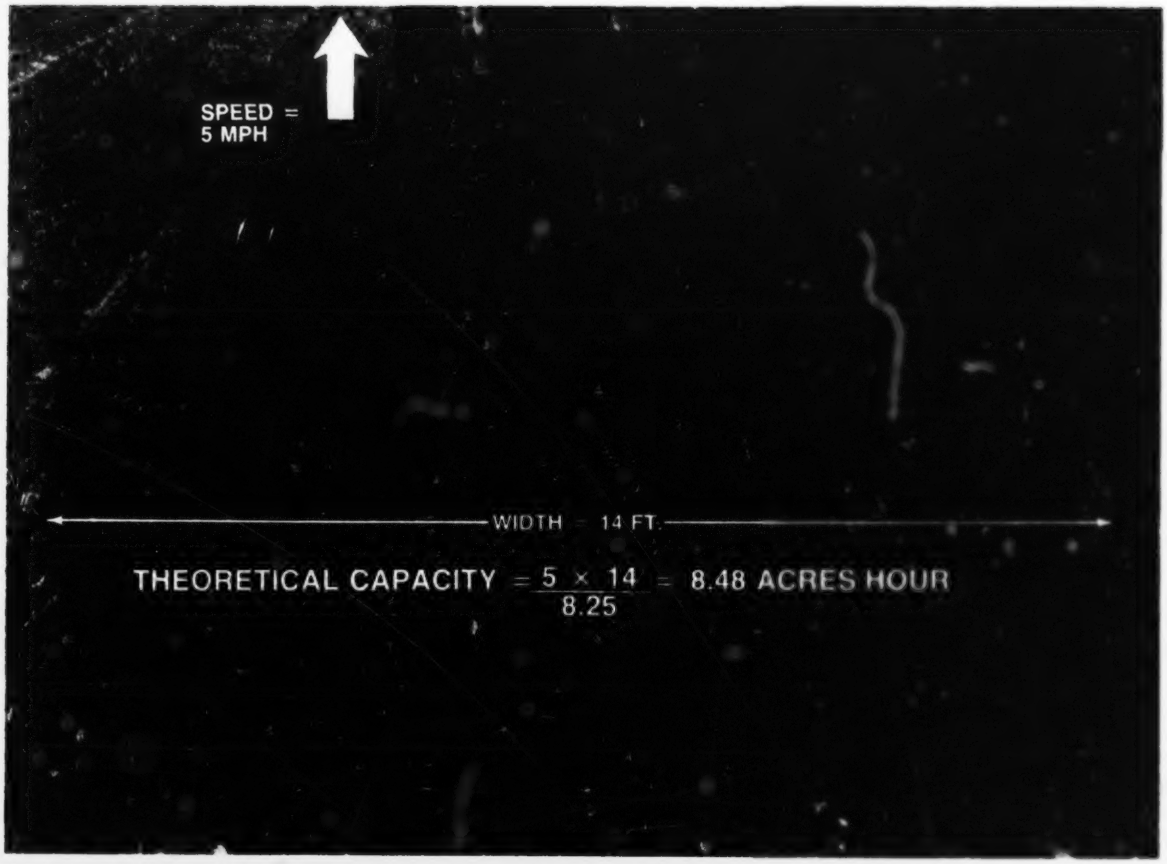


Fig. 13—Theoretical Capacity Is An Instantaneous Capacity For A Given Speed

range transmission provides as many as 16 forward and 6 reverse speeds.

Another type of transmission is hydrostatic drive. It allows operation at the exact speed that allows a machine to perform at its best. The windrower shown in Figure 11 is one example of hydrostatic drive. The operator can vary the speed from one moment to the next to compensate for any variations of crop conditions in the field. Machine speed is determined the same way as with other transmission types.

INCREASING AVERAGE MACHINE WIDTH

Using full machine width is one important way to more efficiently use labor and equipment. The greater the average width of cut, the greater the capacity (Fig. 12). Every machine should be used as close to its full width as possible.

If a 14-foot (4.25-meter), self-propelled windrower is operated for an average width of cut of 13 feet, 2 inches (4 meters); 10 inches (0.25 meters) or nearly 6 percent of the available width is lost. Although a skilled operator probably cannot cut a full 14 feet (4.25 meters), experience with field conditions indicates that an average cutting width of 13 feet, 6 inches (4.1 meters) is easily possibly. Skilled operators might average closer to 13 feet, 8 inches (4.16 meters), but have to watch closely where they are driving.

THEORETICAL CAPACITY

Theoretical capacity is the maximum possible capacity obtainable at a given speed, assuming the machine is using its full width (Fig. 13).

Theoretical capacity is explained in the following example. Suppose a tractor with a 14-foot (4.25-meter) disk travels 5.0 mph (8 km/h). What is the theoretical capacity?

The distance traveled in one hour would be:

5.0 × 5,280 feet = 26,400 feet per hour.

Ⓜ 8 × 1000 meters = 8000 meters per hour

Assuming the disk always cuts the full width of 14 feet (4.25 meters), it would cover:

14 × 26,400 = 369,600 square feet per hour.

Ⓜ 4.25 × 8000 = 34 000 square meters per hour

Because there are 43,560 square feet in an acre, (10 000 square meters in a hectare), the *theoretical capacity* of the disk is:

$\frac{369,600}{43,560} = 8.48$ acres per hour

Ⓜ $\frac{34\,000}{10\,000} = 3.4$ hectares per hour

Theoretical capacity can also be determined with the following formula:

$$\textbf{Theoretical capacity} = \frac{\textbf{Speed} \times \textbf{Width}}{\textbf{8.25}}$$

The constant of 8.25 is derived as follows:

> We want to calculate theoretical capacity in units of acres per hour. We already know that:
>
> $$\text{acres per hour} = \frac{\text{square feet per hour}}{\text{43,560 square feet per acre}}$$
>
> Therefore, to find acres per hour in another way
>
> $$\frac{(\text{Speed, mph}) \times (\text{5,280 feet/mile}) \times (\text{Width, feet})}{\text{43,560 square feet/acre}}$$
>
> To arrive at the answer in acres per hour, use the unit-factor method:
>
> $$\frac{(\text{Speed, }\cancel{\text{miles}}\text{/hour}) \times (\text{5,280 }\cancel{\text{ft.}}/\cancel{\text{mile}}) \times (\text{Width, }\cancel{\text{ft.}})}{\text{43,560 }\cancel{\text{ft.}} \times \cancel{\text{ft.}}\text{/acre}}$$
>
> The next step is to invert the denominator and multiply the units:
>
> $$\frac{\text{Acres}}{\text{Hours}} = \text{Speed} \times \text{Width} \times \frac{5,280}{43,560}$$
>
> Next, divide the numbers in the equation by the common denominator of 5,280 to simplify the equation for theoretical capacity:
>
> $$\text{Acres/Hour} = \frac{\text{Speed, mph} \times \text{Width, feet}}{8.25}$$
>
> Therefore, we have a constant of 8.25 which gives us this formula in acres-per-hour units:
>
> $$\textbf{Theoretical capacity} = \frac{\textbf{Speed} \times \textbf{Width}}{\textbf{8.25}}$$

See page 18 for formula and method of deriving the constant of 10 for theoretical capacity in metric.

Speed must be given in miles per hour and width in feet (kilometers per hour and meters in metric).

Using this formula to determine the theoretical capacity of the disk follows:

$$\text{Theoretical Capacity} = \frac{5 \times 14}{8.25}$$

$$= 8.48 \text{ acres per hour}$$

Fig. 14—Time Lost In Filling Hoppers, Making Turns, And Other Operations Reduces Effective Field Capacity

Ⓜ $\text{Theoretical capacity} = \frac{8 \times 4.25}{10}$

$= 3.4$ hectares per hour

Theoretical capacity cannot be sustained for long periods of time because any field operation will be interrupted by turns, filling hoppers and breakdowns (Fig. 14). Yet, it is valuable information.It gives the maximum capacity which can be used as a basis for evaluating performance of machines and their operators. The *effective field capacity* is always less than the *theoretical capacity.*

EFFECTIVE FIELD CAPACITY

The best way to determine the *effective field capacity* (EFC) of a machine is to make an accurate check of the number of acres (hectares) actually covered or tons handled over a long period of time.

ACRES-PER-HOUR EFC

If a 14-foot (4.25-meter) disk actually covers 70 acres (28 hectares) while operating for 10 hours with no breakdowns, its effective field capacity would be:

70 acres divided by 10 hours or 7.0 acres per hour.

Ⓜ 28 hectares divided by 10 hours or 2.8 hectares per hour

But one day's experience may not give a true picture of the effective field capacity for the season. If the same disk is used for a two-calendar-week period, we might have different figures such as:

Total calendar days = *14*

Total working days = *8*

Total hours in field = *72*

Total acres (hectares) covered = *480 (195)*

$$\text{Effective field capacity} = \frac{\text{Total acres}}{\text{Total hours}} = \frac{480}{72}$$

$$= 6.67 \text{ acres per hour}$$

Ⓜ $\frac{\text{Total hectares}}{\text{Total hours}} = \frac{195}{72} = 2.7$ hectares per hour

Now let's go back and compare the field efficiency for both the one-day and two-week period.

In the one-day period, the capacity was 7.0 acres per hour (2.8 hectares per hour):

$$\text{Field Efficiency} = \frac{\text{Effective field capacity}}{\text{Theoretical capacity}} \times 100$$

$$= \frac{7.0}{8.48} \times 100 = 82.5 \text{ percent}$$

Ⓜ $\frac{2.8}{3.4} \times 100 = 82.4$ percent

But for the two-week period, the field efficiency would be:

$$\text{Field Efficiency} = \frac{6.67}{8.48} \times 100 = 78.7 \text{ percent}$$

Ⓜ $\text{Field Efficiency} = \frac{2.7}{3.4} = 79$ percent

Thus, the field efficiency for the two-week period was lower than for the one-day check.

TONS-PER-HOUR EFC

The effective field capacity for hay and forage equipment is essentially calculated in the same way as acres per hours. In the calculations, tons is substituted as the unit of measure in the place of "acres."

To obtain metric tons per hour, see the section under the heading METRIC EQUIVALENT OF TONS PER HOUR on page 19.

If a self-propelled forage harvester was chopping windrowed alfalfa that yielded one ton per acre, its effective field capacity could be expressed in tons per hour. If 100 acres of the alfalfa is chopped in ten hours with no breakdowns or other delays, its effective field capacity would be:

$$\frac{1 \text{ ton} \times 100 \text{ acres}}{10 \text{ hours}} = 10 \text{ tons per hour.}$$

As in the previous example, one day's experience may not give a true picture of the effective field capacity for the season. If the same forage harvester is used for a four-calendar-week period, different figures might evolve such as:

Total calendar days = *28*

Total working days = *18*

Total hours in field = *180*

Total tons (metric tons) harvested = *1600*

$$\text{Effective Field Capacity} = \frac{\text{Total tons}}{\text{Total hours}} = \frac{1600}{180}$$

$$= 8.89 \text{ tons per hour}$$

Now let's compare the field efficiency for a one-day period and the four-week period.

In the one-day run, the capacity was 10 tons per hour. Theoretical capacity was calculated at 12.5 tons per hour.

$$\text{Field Efficiency} = \frac{\text{EFC (tons per hour)}}{\text{Theoretical Capacity}} \times 100$$

$$= \frac{10}{12.5} \times 100 = 80.0 \text{ percent}$$

But for the four-week period, the field efficiency would be:

$$\text{Field Efficiency} = \frac{8.89}{12.5} = 71.1 \text{ percent}$$

CAPACITIES IN METRICS

Speed times width equals Field Capacity:

$$\frac{92 \text{ meters}}{\text{minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} \times 6.1 \text{ meters} \times \frac{1 \text{ hectare}}{10\,000 \text{ m}^2} =$$

$$3.35 \text{ hectares per hour}$$

Kilograms harvested per hour equals Material Capacity:

$$\frac{227\,000 \text{ grams}}{\text{minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} \times \frac{1 \text{ kilogram}}{1000 \text{ grams}}$$

$$= 13\,620 \text{ kilograms per hour}$$

Material Capacity in metric tons per hour:

$$\frac{13\,620 \text{ kilograms}}{\text{hour}} \times \frac{1 \text{ tonne}}{1000 \text{ kilograms}} = 13.6 \text{ tonnes per hour}$$

Total amount of material per hour:

$$\frac{227 \text{ kg}}{\text{minute}} \times \frac{60 \text{ minutes}}{1 \text{ hour}} = 27\,240 \text{ kilograms per hour}$$

$$= 27.24 \text{ tonnes per hour}$$

Theoretical capacity in the metric system is:

$$\text{Theoretical Capacity} = \frac{\text{speed} \times \text{width}}{10}$$

Fig. 15—Use Realistic Field Capacity Based On Average For The Season

It is derived as follows:

$$\text{hectares per hour} = \frac{\text{square meters per hour}}{\text{10,000 square meters/hectare}}$$

$$\text{hectares per hour} = \frac{\text{speed, meters/hr} \times \text{width, meters}}{10{,}000}$$

Speed is measured in kilometers/hr, 1 km = 1000m

so theoretical capacity, ha/hr =

$$\frac{\text{speed, km/hr} \times \text{width, m}}{10}$$

Effective field capacity would be:

$$\frac{\text{speed, km/hr} \times \text{width, m}}{10} \times \frac{\text{field eff. \%}}{100}$$

METRIC EQUIVALENT OF TONS PER HOUR

A metric ton is 1000 kilograms or 2,205 pounds. One hectare = 10,000 square meters = 2.471 acres. One kilogram = 2,205 pounds. One pound = 0.4536 kg One meter = 100 centimeters.

If a forage harvester can average 15 tons (U.S. Customary) per hour for a 10-hour day, it could harvest 150 tons.

In metric units the total harvest would be 150 × 2,000 or 300,000 pounds.

Since the metric ton is 2,205 pounds, 300,000 ÷ 2,205 = 136 tons per hour.

If the yield is 5 tons per acre (English) the yield in metric units would be 5 tons × 2,000 lbs/ton × 2.471 acres/ha = 24,710 pounds/ha

24,710 pounds/ha ÷ 2,205 pounds/metric ton = 11.2 tons (metric)/ha

SUMMARY

Measuring machine capacity is basic to machinery management. Machine capacity is the machine's rate of performance, usually reported in terms of *quantity per time*.

The three possible methods of measuring machine capacity are:

- **Field capacity**
- **Material capacity**
- **Throughput capacity**

Throughout this book we will use field capacity, measured in acres per hour (hectares per hour), and material capacity, measured in pounds (kilograms) or tons per hour, as the two most common methods of measuring machine capacity. Other methods of measuring machine capacity are generally too technical for common farm application.

Speed, width and *efficiency* are the three factors used to determine machine capacity.

Theoretical capacity uses two of the factors—speed and width. It is the maximum possible capacity obtainable at a given speed, assuming the machine is using its full width.

Effective field capacity brings in the factor of efficiency. This capacity determination represents the real-life or actual capacity obtainable over a period of time.

A comparison of the one-day and two-week field efficiencies in this chapter shows a mistake commonly made by farm operators or managers. The mistake is the natural tendency to remember only the best working days and to use these capacity figures for planning and scheduling purposes. ***When scheduling operations or sizing machines for the future, use realistic field capacities as determined over the full season of use (Fig. 15).*** Use accurate capacities for the same machine in different operations, such as disking stalks and smoothing soil prior to planting.

CHAPTER QUIZ

1. Name the three factors that determine capacity of a machine.

2. List three or four operations where it is important for a machine to run at the proper speed.

3. (Multiple choice) If you are disking in a field 1056 feet long and travel from one end to the other in 2.4 minutes, the speed in miles per hour is:

a. 0.5 mph

b. 5.0 mph

c. 6.5 mph

4. You want to adjust a tractor with a mounted sprayer to run 4.6 miles per hour. How many seconds should it take to travel 88 feet?

5. True or false? "The theoretical capacity of a combine with a 20-foot header traveling 4.0 miles per hour is 9.7 acres per hour."

6. (Multiple choice) If the theoretical capacity of a 14-foot self-propelled windrower is seven acres per hour and it cuts 63.7 acres in 13 working hours, what is the field efficiency?

a. 70 percent

b. 41 percent

c. 91 percent

7. What is the effective field capacity of a 6-row, 30-inch header equipped corn combine traveling 3.33 miles per hour, assuming a field efficiency of 60 percent?

8. (Fill in the blank.) You have a broadcast sprayer that needs to be calibrated. In a speed check, it travels 88 feet in 12 seconds. The speed is _______ miles per hour.

9. (Multiple choice) How fast would you have to operate a tractor and 4-bottom, 18-inch plow to average three acres per hour? Assume a field efficiency of 82.5 percent.

a. 4.12 mph

b. 5 mph

c. 5.4 mph

10. You need to estimate the effective capacity of a corn planter that you are thinking of buying. Describe the four steps you would follow.

Ⓜ 11. (Multiple choice) If your tractor travels 400 meters in 4 minutes, what is the speed in kilometers per hour?

a. 6.0 km/h

b. 9.7 km/h

c. 5.1 km/h

Ⓜ 12. A combine with a 6-row corn head adjusted for 76-centimeter row spacing harvests at 6 kilometers per hour. What is the theoretical capacity in hectares per hour?

Ⓜ If field efficiency is 62 percent, what is the effective field capacity in hectares per hour?

Ⓜ 13. (Fill in the blank) The same broadcast sprayer from question 8 once again needs to be calibrated. In this instance, it traveled 16.7 meters in 7.5 seconds. The speed is ______ kilometers per hour.

3
Improving Field Efficiency

Fig. 1—A Preseason Checkup Improves Field Efficiency By Helping To Eliminate Breakdowns

INTRODUCTION

The ability to improve field efficiency is the next important step in developing machinery management skills. There are several important reasons why a machine may have a certain field efficiency. Some lost-time factors are built into the operation. Other lost-time factors can be eliminated by *good planning* and *management* (Fig. 1). Typical factors causing lost time include:

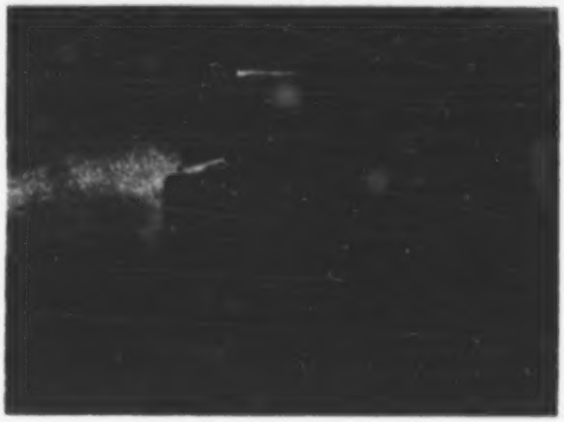
- *Using partial capacity*
- *Filling procedures*
- *Unloading procedures*
- *Turning and field conditions*
- *Unclogging machines*
- *Making adjustments*
- *Repairing breakdowns*
- *Servicing machines*
- *Stopping to rest*
- *Changing operators*
- *Checking machine performance*
- *Having unmatched machines*

Any of these factors may contribute greatly to lost time. Let's discuss these factors and their effects on field efficiency in more detail.

UNUSED CAPACITY

The way an individual operates a machine determines how much of its potential capacity is actually used. This is true in cases of using the fullest possible width of a machine or keeping the machine adjusted for maximum capacity.

Fig. 2—Drive To Utilize Full Operating Width Of Implements



A 28-foot (8.5-meter) field cultivator that overlays 3 feet (0.9 meters) each trip over a field loses 11 percent of its effective capacity. A 12-foot (3.6-meter), pull-type windrower that cuts only 11 feet (3.35 meters) loses 8 percent of its width. A 4-bottom, 14-inch (35-cm) plow that cuts only 10 inches (25.4 cm) with the front bottom is losing 7 percent. A forage harvester with improperly-positioned or dull knives requires more power and results in more breakdowns because of increased strain on machine components.

These are just a few examples of how improper field operation or adjustment can affect machine capacity. Proper field operation and machine adjustments result in greater capacity for any machine. Average values of efficiency losses for unused width will range from five to ten percent, but this type of loss can be reduced to four percent or less by better planning, careful driving and correct machine adjustment.

FILLING PROCEDURES

Proper filling procedures are particularly important to field efficiency because they are part of seeding or planting operations for crops. Time losses of up to 20 percent are not unusual for refilling hoppers on a planter or drill. If travel time is also needed to refill sprayer tanks, the time lost may be nearer to 30 percent (Fig. 3).

Fig. 3—Efficient Filling Procedures Improve Field Efficiency

Fig. 4—Augering Of Materials Increases Productivity

One way to improve field efficiencies with filling operations is to use larger hoppers, portable augers and nurse tanks with transfer pumps (Fig. 4). It is important to complete the planting as quickly as possible from a timeliness standpoint. Therefore, constantly look for ways to increase field efficiency. It may be better to refill hoppers in the middle of long fields than to refill boxes that may be one-third to one-half full. With proper organization and mechanization, these time losses can be reduced by 50 percent.

UNLOADING PROCEDURES

If excessive maneuvering is required to spot trucks or wagons to unload the combine, it's not unusual to use 20 to 30 percent of the total field time in unloading, particularly if the unloading auger is slow. Skilled operators can cut this time in half by minimizing turning time and spotting the truck or wagon so it is conveniently located on the turning path. This lost time is virtually eliminated by unloading on-the-go (Fig. 5).

Fig. 5—Unload On-The-Go For Maximum Field Efficiency

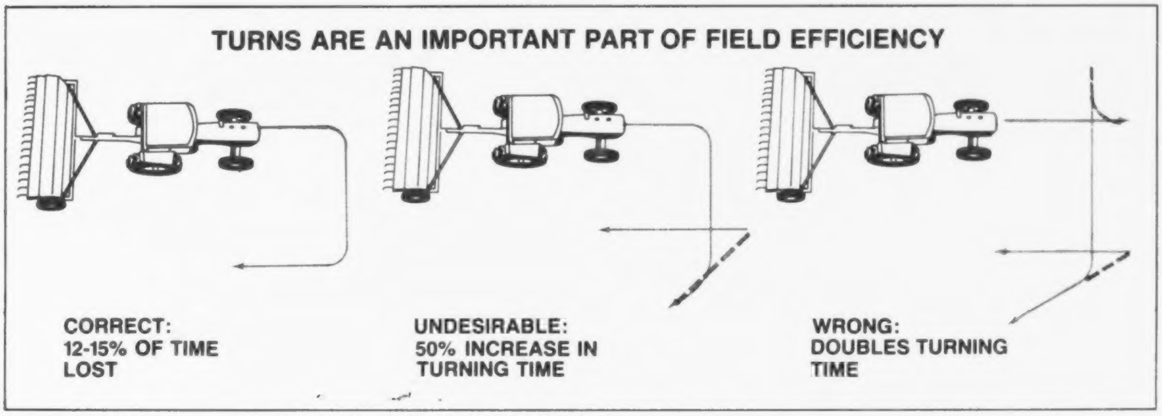
TURNING TIME AND FIELD CONDITIONS

Turning time is the one loss factor built into every field operation, but can be kept to a minimum by planning fields with longer rows (Fig. 6). Turning time can run as high as 25 percent of the total field time, but more typically the range will be from 12 to 15 percent.

A normal turn at the end of a field is one which can be made with one continuous motion and requires little, if any, extra motion to return to the centerline. If the space at the end of the field is too narrow for a complete turn and requires backing for completion, as much as 50 percent more turning time will be required.

If there is no space at the end of a field for a turn and the entire operation must be completed by backing, turning time may be more than doubled. Other time losses are caused by rough field conditions, obstructions and ditches.

Fig. 6—Turning Time Needs To Be Kept To A Minimum


TURNS ARE AN IMPORTANT PART OF FIELD EFFICIENCY
CORRECT:
12-15% OF TIME
LOST
UNDESIRABLE:
50% INCREASE IN
TURNING TIME
WRONG:
DOUBLES TURNING
TIME

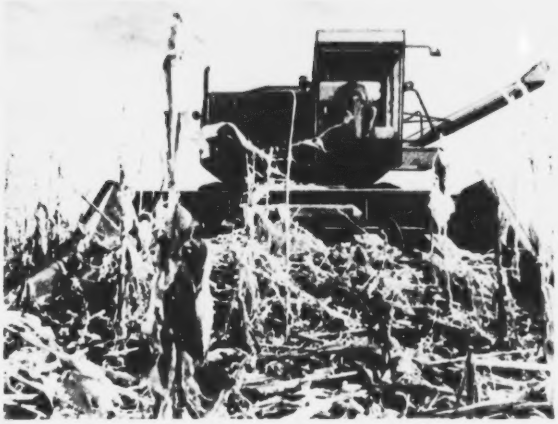


Fig. 7—Poor Harvest Conditions Increase Clogging And Reduce Effective Field Capacity

UNCLOGGING MACHINES

One time factor that can be nearly eliminated by good management is unclogging machines. It is also a main reason for an unusually high percentage of lost field time and accidents. Under severe conditions the effective field capacity may be only one-third or one-half of what it would be without clogging problems (Fig. 7).

Fig. 8—Keep The Machine In Proper Condition To Avoid Excessive Clogging

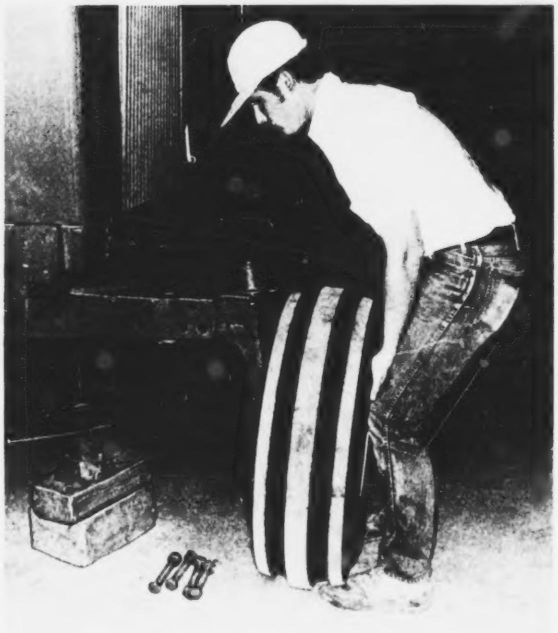


Fig. 9—Making Adjustments Before Going To The Field Improves Field Efficiency

What causes clogging? There are three main reasons. The most likely reason for clogging is overloading the machine. In other words, trying to make the machine do more than it is designed to handle—which is typical of the operator in a hurry. Even if the machine is in top shape, it can still plug up if operated over its designed capacity.

Secondly, there could be something wrong with the machine—dull knives, faulty slip clutches, loose belts or improper adjustment. Keeping the machine in top condition avoids excessive clogging (Fig. 8).

Finally, trying to operate the machine when conditions are not right can cause clogging. The crop may be too wet or too dry. The ground may be too wet (for tillage) or there may be too much trash.

By checking out machines ahead of the season and not crowding them in the field, less clogging will occur and field efficiency will improve substantially.

MAKING ADJUSTMENTS

With most machines, it is necessary to make adjustments before going to the field (Fig. 9). Some machines, like combines or balers, have to be adjusted occasionally in the field as crop conditions vary throughout the day. For maximum performance from forage harvesters, for example, rotating knives should be kept sharp and the stationary knife or

Fig. 10—Proper Servicing Helps Prevent Field Breakdowns

shear bar kept properly adjusted. Always consult the operator's manual for making adjustments to get the maximum performance from machines.

The worst mistake made with complex machines like combines or planters is to wait until getting to the field to make adjustments. Have the machine checked over, repaired, adjusted and ready for operation before going to the field.

REDUCING BREAKDOWNS

It is impossible to predict when some part of a machine will fail, but many machine breakdowns in the field can be avoided by making thorough inspections before and during operation. Watch for signs that will help avoid breakdowns. Losing three or four days of a busy season is not only expensive, but it throws everything else off schedule. To help eliminate or reduce breakdowns, follow these rules:

1. Inspect and repair machines well ahead of the use season.
2. Practice preventive maintenance.
3. Avoid rocks, holes, obstructions.
4. Drive cautiously in rough fields.
5. Don't overload the equipment.
6. Check out strange sounds, vibrations or smells.
7. Make small repairs when needed.
8. Use periodic checkups to locate potential trouble.
9. Keep all power transmitting members adjusted, aligned and lubricated.

SERVICING MACHINES

Most maintenance should take place before or after the day's work, but many machines require frequent lubrication during the day. Such maintenance cannot be neglected (Fig. 10). It is far better to use extra time for complete and thorough machine servicing than to have field breakdowns costing hours or even days.

REST STOPS

Short but frequent breaks or rest stops are desirable and necessary from both the standpoint of safety and improved performance (Fig. 11). When the operator has to continually concentrate on a job, a short break every hour or so will increase alertness, reduce accidents and improve the quality of work.

On the other hand, avoid prolonged or unnecessary rest stops. They cut heavily into a day's production. Allowing an extra 20 minutes in the morning and another 20 minutes in the afternoon other than regular rest breaks can reduce effective field capacity by seven to eight percent.

Think through management decisions during rest breaks or the night before, rather than while operating a machine. In the interest of safety, always devote all attention to the machine being operated rather than trying to make management decisions.

Fig. 11—Rest Breaks Make You More Alert And Improve Quality Of Work

Fig. 12—Changing Operators And Servicing Machines In The Field Increases Efficiency

CHANGING OPERATORS

Changing operators usually applies to larger operations and requires little extra time (Fig. 12). The best way to save time and improve field efficiency is to service machines and change operators right in the field. Running into the service yard for refueling, greasing and other service operations means unnecessary time loss.

CHECKING MACHINE PERFORMANCE

Only a few minutes a day is required to stop occasionally to inspect a machine and its performance (Fig. 13). This practice, while it takes time, goes a long way toward improving field efficiency. Spot checking machine performance, looking for loose bolts or worn parts, often prevents bigger problems.

Fig. 13—Take Time To Check Machine Performance

UNMATCHED MACHINE CAPACITY

One major cause of an inefficient operation is a system of unmatched machines. To match machines in a system, it is important to follow the principle of increasing capacity with each operation.

In using this principle, each machine involved in succeeding steps in the system needs to provide greater capacity than the preceding machine. If the machine providing the third step in a four-step system has a lower capacity than one of the machines involved in the first two steps, the other machines will be idle part of the time. With the costly labor and machines involved, waiting can be expensive.

A good example of such a system is a corn harvesting operation. In order to set up an example of a system that uses the maximum efficiency of the machines involved, we will use these three steps:

Step 1—Harvest with a corn combine. Capacity is 400 bushels (10 170 kilograms) per hour or 4,000 bushels (101 700 kilograms) in a ten-hour day.

Step 2—Haul to processing center. Potential hauling capacity is 450 bushels 11 440 kilograms per hour or 4500 bushels (114 400 kilograms) in a ten-hour day.

Step 3—Processing, which includes drying and moving to storage. Drying rate is 300 bushels (7627 kg) per hour or 4800 bushels (122 035 kg) in 16 hours. This excess capacity allows for future expansion of production and is considered a good management procedure.

In this simplified example, the most important part of the operation is getting the corn out of the field.

Each process that follows has an increasing capacity capability. This is to make sure that the steps following harvesting keep pace with the initial or primary harvesting operation. Be sure to keep the capacity of each machine in the system in mind when planning operations. Always allow adequate capacity in each machine to "keep up" with the capacity of the previous operation or "bottlenecks" will result.

SUMMARY

The upper limits of field efficiencies apply to long fields with only a small time loss for turning and other essentials. For maximum field efficiencies there can be no time lost for such things as unplugging or breakdowns. However, the better operators will improve the long-run field efficiencies by servicing machines periodically, checking adjustments and keeping their machines in top mechanical condition. The following table lists ranges in field efficiencies.

FIELD EFFICIENCY TABLE

OPERATION	FIELD EFFICIENCY, PERCENT
Tillage	
Moldboard Plow	75-85%
Disk Harrow, Disk Plow	77-90%
Field Cultivator	75-85%
Spring-Tooth or Spike-Tooth Harrow	65-80%
Cultivation	
Row Crop	65-80%
Rotary Hoe	75-85%
Seeding	
Corn Planter	
1. Corn Only	60-75%
2. With Fertilizer and/or Pesticide Attachment	45-65%
Grain Drill	65-80%
Broadcast	65-70%
Harvesting	
Mower	75-85%
Rake	65-90%
Baler	65-80%
Loose Hay Stacking Wagon	65-80%
Forage Harvester	50-70%
Combine	60-75%
Corn Picker	55-70%
Cotton Picker	60-75%
Swather	70-85%
Miscellaneous	
Sprayer	55-65%

CHAPTER QUIZ

1. (Underline correct answer.) If a 14-foot disk overlaps an average of 20 inches with each trip, (10.0) (12.0) (18.0) percent of the width is lost.

2. Why does field efficiency increase with field length?

3. Does field efficiency stay the same if speed is doubled? Why?

4. True or false? "An 8-row planter has exactly double the capacity of a 4-row planter if the speed of planting is identical."

5. List three items the average operator can do to improve field efficiency.

Ⓜ 6. A self-propelled combine with a 6.1-meter head averages cutting 5.8 meters with each pass. What percent loss in field efficiency is due to the overlapping, or unused width?

Ⓜ 7. (Multiple choice) If the combine in problem 6 averages 6.5 kilometers per hour and has a field efficiency of 75 percent, what is the effective capacity in hectares per hour? (Hint: Use actual cutting width of 5.8 meters.)

a. 2.25 ha/hr

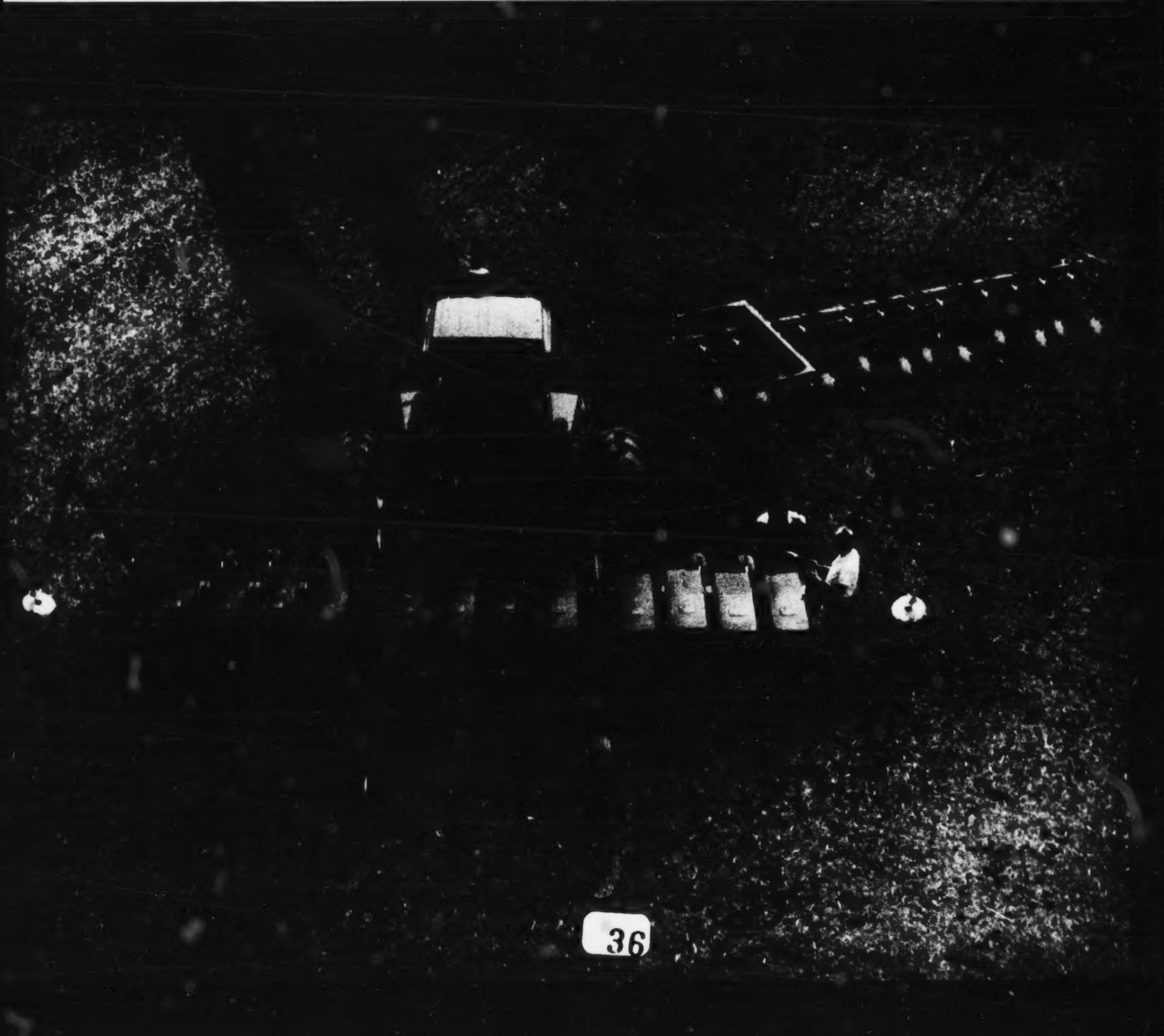
b. 3.31 ha/hr

c. 2.83 ha/hr

Ⓜ 8. (Fill in the blank.) If the field efficiency for the combine in problem 7 drops to 60 percent, the effective field capacity would be ______ ha/hr. How much less would the combine harvest in a 10-hour day when operating at the lower field capacity?

4

Matching Machine Size and Capacity



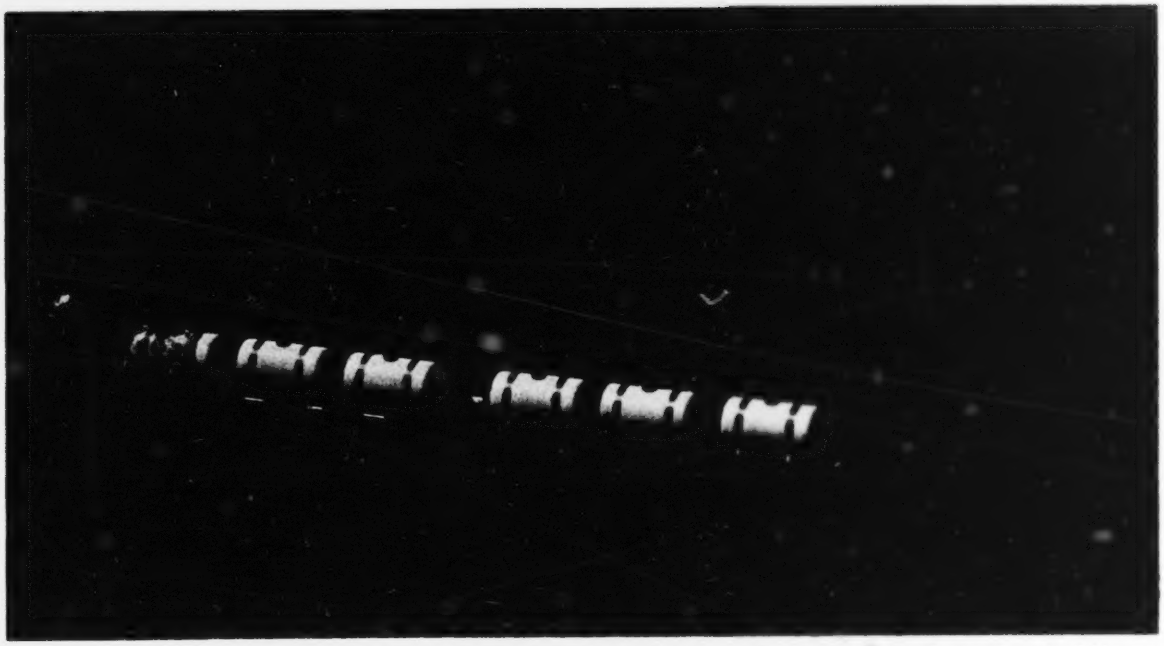


Fig. 1—Proper Machine Size Means Having Adequate Capacity To Complete Critical Field Operations During The Working Time Available

INTRODUCTION

Selecting machine size is an important part of machinery management for two main reasons. First of all, machines must be the right size for the amount of work to be done. Secondly, a machine must be a proper capacity match for other related equipment.

Selecting machine size involves fitting the proper size equipment to the amount of work for a given period of time (Fig. 1). Matching tractors with the right equipment will also be covered in this chapter.

In order to fit machine size to the amount of work which has to be completed in a specific length of time, it will be necessary to have a complete understanding of *effective field capacity* (Fig. 2).

In this chapter, we will also become more familiar with theoretical field capacity and field efficiency.

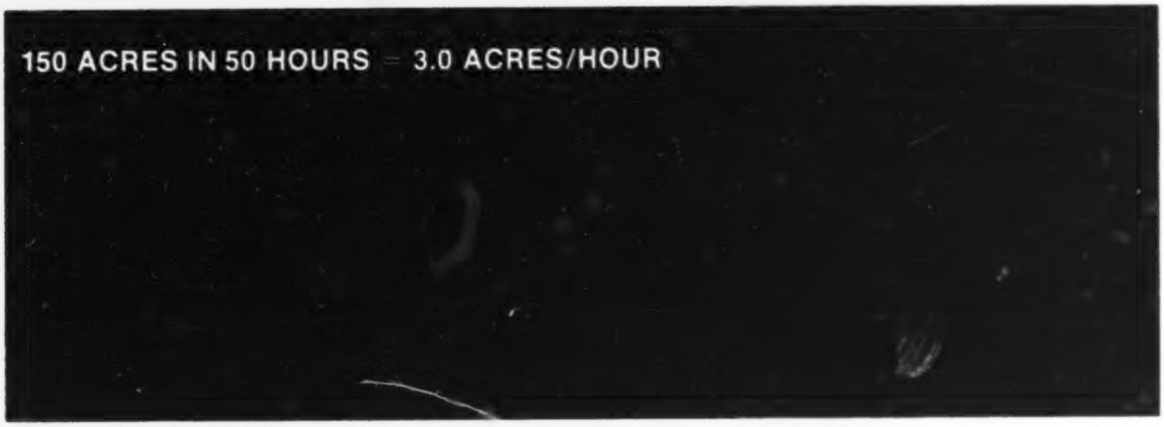


Fig. 2—By Knowing Available Working Time And Amount Of Work To Be Done, You Can Determine Required Capacity

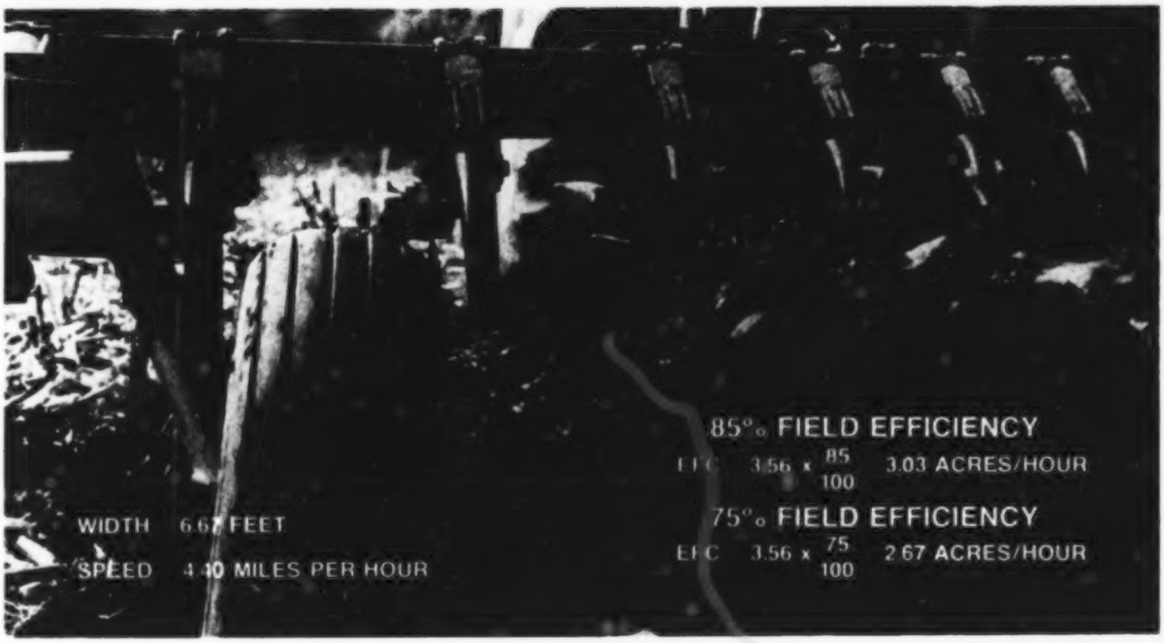

85% FIELD EFFICIENCY
EFC 3.56 x 85/100 3.03 ACRES/HOUR
75% FIELD EFFICIENCY
EFC 3.56 x 75/100 2.67 ACRES/HOUR
WIDTH 6.67 FEET
SPEED 4.40 MILES PER HOUR

Fig. 3—Reducing Field Efficiency From 85 Percent To 75 Percent Cuts Effective Capacity From 3.03 Acres Per Hour To 2.67 Acres Per Hour

ESTIMATING EFFECTIVE FIELD CAPACITY

By combining the factors of theoretical field capacity (TFC) of a machine with its field efficiency, it is possible to calculate the effective field capacity (EFC). In many places throughout the book the following abbreviations will be used:

- EFC (Effective Field Capacity)
- TFC (Theoretical Field Capacity)

Note: See section at the end of this chapter for metric equivalents for the following formulas.

Suppose we have a 5-bottom, 16-inch plow and want to find both the theoretical field capacity (TFC) and the effective field capacity (EFC). The plowing width is 6.67 feet in a field approximately 2600 feet long at a speed of 4.4 miles per hour.

$$\text{TFC} = \frac{\text{Width} \times \text{Speed}}{8.25} = \frac{6.67 \times 4.4}{8.25}$$

$$= 3.56 \text{ acres per hour}$$

Effective field capacity (EFC) can be determined by combining the formula for theoretical field capacity (TFC) and field efficiency.

$$\text{EFC} = \frac{\text{Width, feet} \times \text{Speed, mph}}{8.25} \times \frac{\text{Field Efficiency}}{100}$$

This formula is the same as:

$$\textbf{EFC} = \textbf{TFC} \times \frac{\textbf{Field Efficiency}}{\textbf{100}}$$

Because the field is rather long, we will use a field efficiency of 85 percent. Longer fields have higher percentages of time spent working compared to turning. So using the formula, we see that:

$$\text{EFC} = 3.56 \times \frac{85}{100} = 3.03 \text{ acres per hour}$$

In other words, the actual capacity is 85 percent of the theoretical capacity (Fig. 3).

Suppose the plow is used in a short, irregular field? How would the reduced field efficiency change the effective field capacity? If the field efficiency drops from 85 percent to 75 percent, the new effective field capacity will be:

$$\text{EFC} = 3.56 \times \frac{75}{100} = 2.67 \text{ acres per hour}$$

Lowering the field efficiency from 85 percent to 75 percent would decrease effective capacity by 0.36 acres per hour, 3.6 acres in 10 hours or 36 acres in 100 hours (Fig. 3). Always be thinking of ways to improve field efficiency because the increased capacities that result mean a direct cost savings (Fig. 4).

Let's try another example of calculating effective field capacity. A forage harvester is chopping haylage that has been cut and windrowed by a 14-foot windrower. The forage harvester is traveling at a

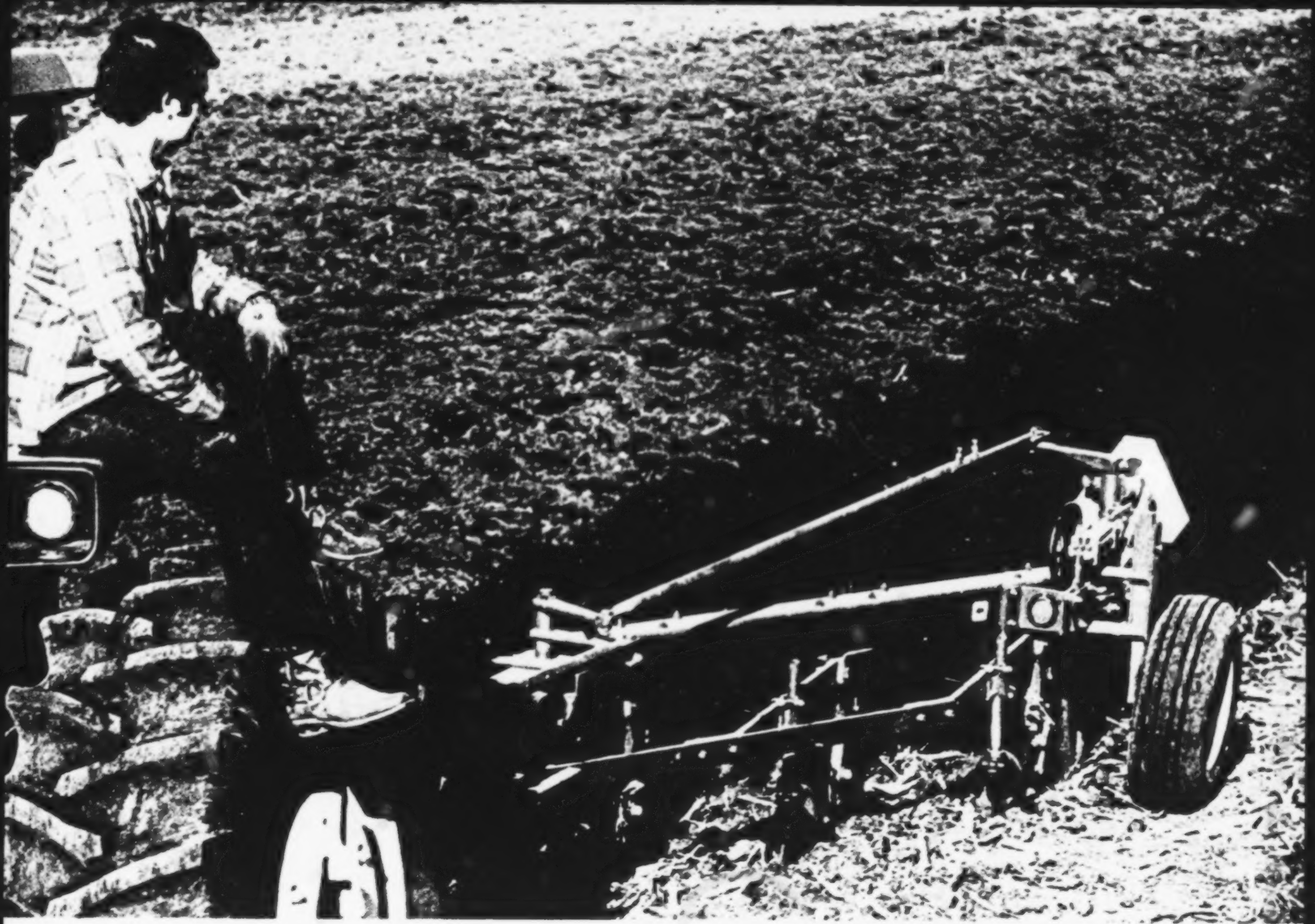


Fig 4—Keep Thinking Of Ways To Improve Field Efficiency

speed of 3.6 miles per hour in a field 2.000 feet in length. and the hay is yielding 3.6 tons per acre. First calculate theoretical field capacity:

$$\text{TFC} = \frac{14 \times 3.6}{8.25} = 6.1 \text{ acres per hour}$$

Because we want our answers in "tons per hour", multiply the acres-per-hour theoretical field capacity by the tons-per-acre yield:

$$\text{TFC (tons per hour)} = \frac{6.1 \text{ acres}}{\text{hour}} \times \frac{3.6 \text{ tons}}{\text{acre}}$$

$$= 22.0 \text{ tons per hour}$$

After determining that field efficiency is 70 percent because of the process of changing wagons after each load. calculate the effective field capacity:

$$\text{EFC} = \frac{22.0 \text{ tons}}{\text{hour}} \times \frac{70}{100} = 15.40 \text{ tons per hour}$$

Once again. by simply using different field efficiencies it is easy to see why it is important to always have the best field efficiency possible.

Finally, let's use an example of a corn combine. Assume a 6-row. 30-inch-row corn head equipped combine is working at a speed of 3.2 miles per hour. With long rows. well-organized unloading patterns and no breakdowns. field studies indicate that a field efficiency of 70 percent can be achieved (Fig. 5).

$$\text{Width} = \frac{6 \text{ rows} \times 30 \text{ inches}}{12 \text{ inches}} = 15 \text{ feet}$$

$$\text{EFC} = \frac{15 \text{ feet} \times 3.2 \text{ mph}}{8.25} \times \frac{70}{100}$$

$$= 4.07 \text{ acres per hour}$$

USING THE NOMOGRAPH

There is a way to determine field capacity without using a formula. This device is a nomograph or alignment chart (Fig. 6).

The example shown on the nomograph is for a 6-row. 30-inch planter traveling 4.5 mph (Fig. 7). Because the planter is applying starter fertilizer, herbicides and insecticides in a field with one-quarter mile rows, field efficiency, as shown by field studies, will be taken as 60 percent.

First, let's solve for theoretical and effective field capacity by our formulas:

$$\textbf{Width} = \frac{6 \text{ rows} \times 30 \text{ inches}}{12} = 15.0 \text{ feet}$$

$$\textbf{TFC} = \frac{W \times S}{8.25} = \frac{15.0 \text{ feet} \times 4.5 \text{ mph}}{8.25}$$

$$= 8.2 \text{ acres per hour}$$

$$\textbf{EFC} = \text{TFC} \times \frac{\text{Field Efficiency}}{100} = 8.2 \times \frac{60}{100}$$

$$= 4.9 \text{ acres per hour}$$

(See formula with metric equivalents on page 37.)

The same problem is solved on the nomograph by drawing two straight lines. The first line is drawn through 4.5 on the left-hand scale and 15.0 feet on the theoretical width scale. The theoretical capacity line is intersected at 8.2 acres per hour (Fig. 7). The second line starts at the same exact point (8.2) on the middle line and is drawn through 60 percent field efficiency, intersecting the right-hand scale at 4.9 acres per hour (Fig. 8).

With a little thought and practice you can also solve for speed, width or field efficiency, using either the formulas or the nomograph.

$$\textbf{Speed} = \frac{\text{Acres per hour} \times 8.25}{\text{Width}} \times \frac{100}{\text{Field Efficiency}}$$

$$\textbf{E.F.C.} = \frac{15\text{x}3.2}{8.25} \text{ x } \frac{70}{100} = \textbf{4.07 ACRES/HOUR}$$

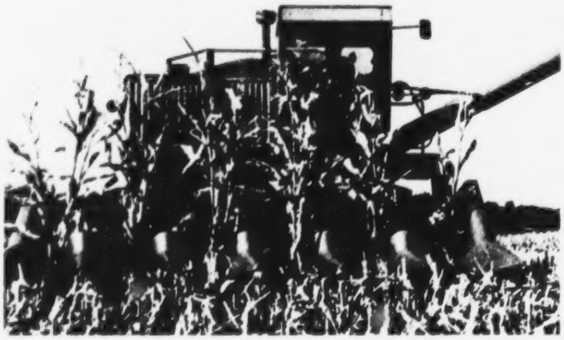


Fig. 5—A 6-Row, 30-Inch Corn Combine Will Average 4.07 Acres Per Hour At 3.2 Miles Per Hour, 15-Foot Width And 70 Percent Field Efficiency

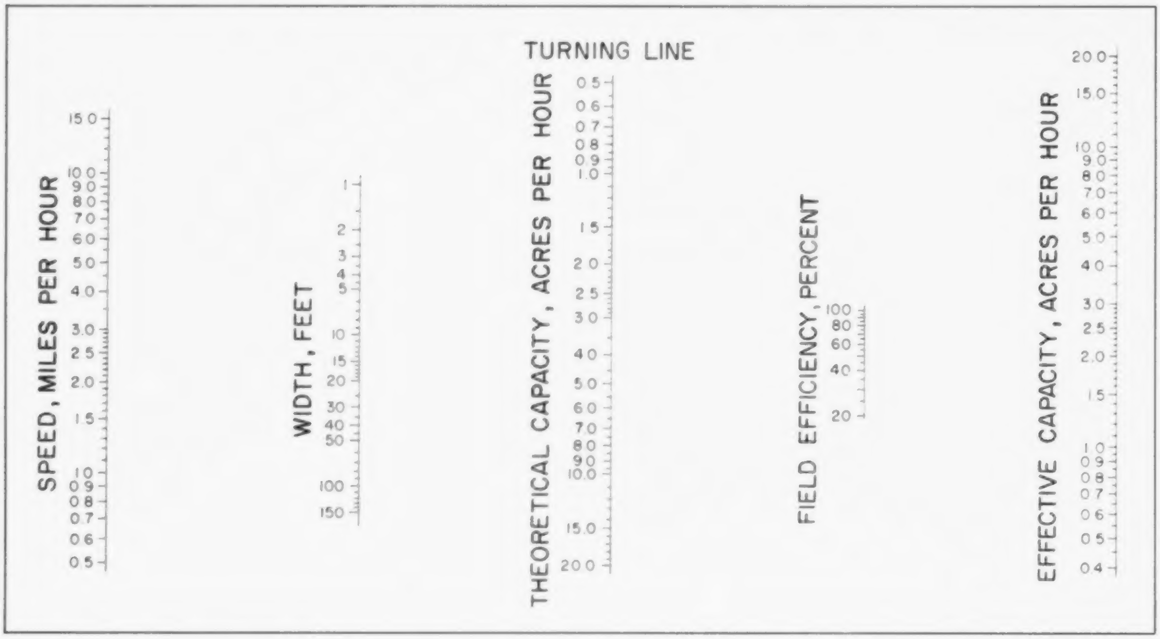
$$\textbf{Width} = \frac{\text{Acres per hour}}{\text{Speed}} \times 8.25 \times \frac{100}{\text{Field Efficiency}}$$

$$\textbf{Field Efficiency} = \frac{\text{Acres per hour} \times 8.25 \times 100}{\text{Speed} \times \text{Width}}$$

Let's try this formula on an example:

How wide of a disk harrow is needed for an effective field capacity of six acres per hour, assuming a field efficiency of 80 percent and a speed of five miles per hour (Fig. 9)?

Fig. 6—A Nomograph For Determining Machine Capacity


TURNING LINE
SPEED, MILES PER HOUR
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.9
0.8
0.7
0.6
0.5
WIDTH, FEET
1
2
3
4
5
10
15
20
30
40
50
100
150
THEORETICAL CAPACITY, ACRES PER HOUR
0.5
0.6
0.7
0.8
0.9
1.0
1.5
2.0
2.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
15.0
20.0
FIELD EFFICIENCY, PERCENT
100
80
60
40
20
EFFECTIVE CAPACITY, ACRES PER HOUR
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4

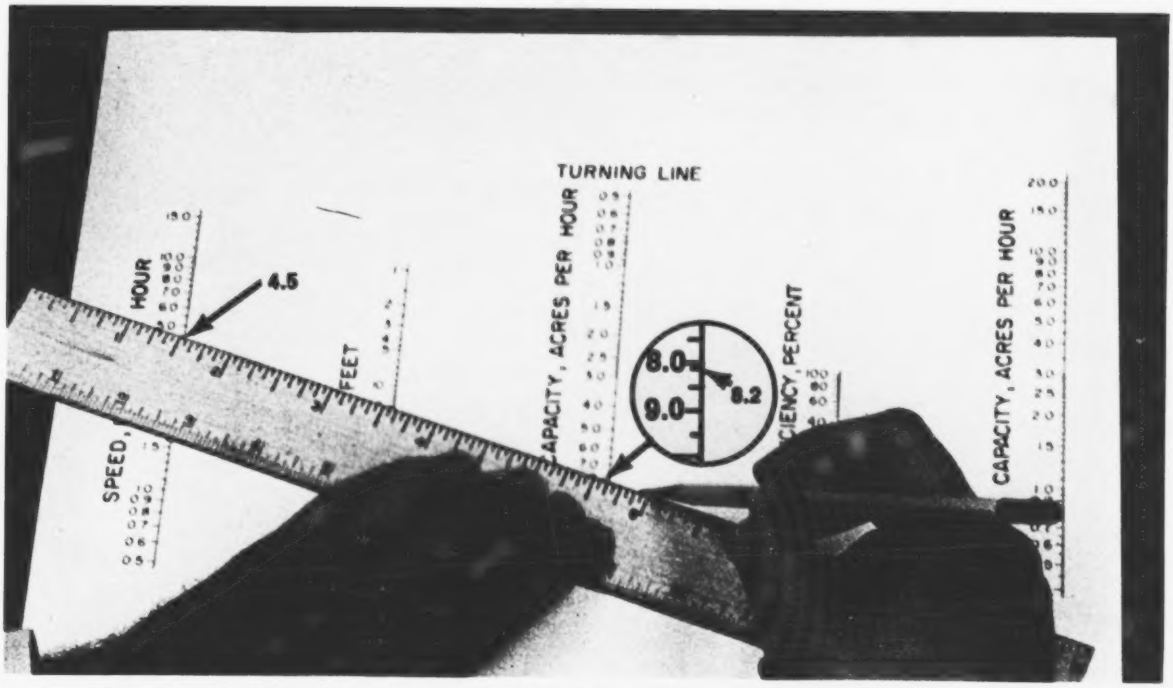
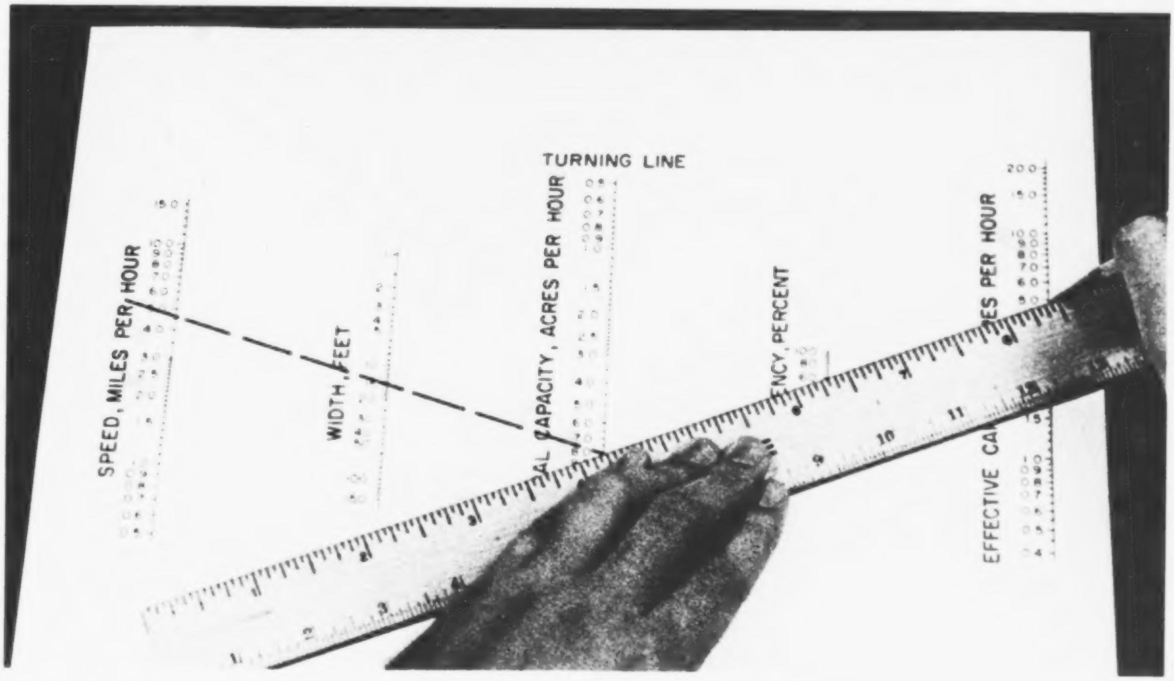
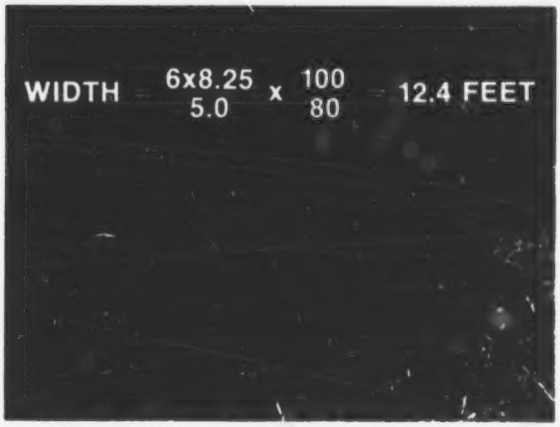

TURNING LINE
SPEED, HOUR
4.5
FEET
CAPACITY, ACRES PER HOUR
8.0
9.0
8.2
CIENCY, PERCENT
CAPACITY, ACRES PER HOUR

Fig. 7—A 6-Row, 30-Inch Planter Would Have A Theoretical Capacity Of 8.2 Acres Per Hour At 4.5 MPH

Fig. 8—Effective Field Capacity Is 4.9 Acres Per Hour At 60 Percent Field Efficiency


TURNING LINE
SPEED, MILES PER HOUR
WIDTH, FEET
AL CAPACITY, ACRES PER HOUR
ENCY, PERCENT
EFFECTIVE CA ES PER HOUR



$$\text{WIDTH} = \frac{6\text{x}8.25}{5.0} \text{ x } \frac{100}{80} = 12.4 \text{ FEET}$$

Fig. 9—Determining Disk Width Needed To Disk Six Acres Per Hour At Five Miles Per Hour With 80 Percent Field Efficiency

First solve by formula:

$$\textbf{Width} = \frac{6 \text{ Acres/hour}}{5 \text{ mph}} \times 8.25 \times \frac{100}{80} = \frac{49.50}{4} = 12.4 \text{ feet}$$

See formula with metric equivalents on page 37. Then turn to page 168 in the Appendix to find the nomograph (calibrated in metric equivalents) used to determine this width.

Now try the nomograph. Start at six acres per hour and draw a line through 80 percent field efficiency, intersecting the middle scale at 7.5 acres per hour (the needed theoretical capacity) (Fig. 10). Draw a second straight line from 7.5 on the middle scale through five miles per hour on the left-hand scale. The second line indicates the width needed by intersecting the width scale at 12.4 feet (Fig. 10). The nomograph can be used to find one unknown as long as the values of the other three factors are known.

MATCHING MACHINE SIZE TO FIT TIME AVAILABLE

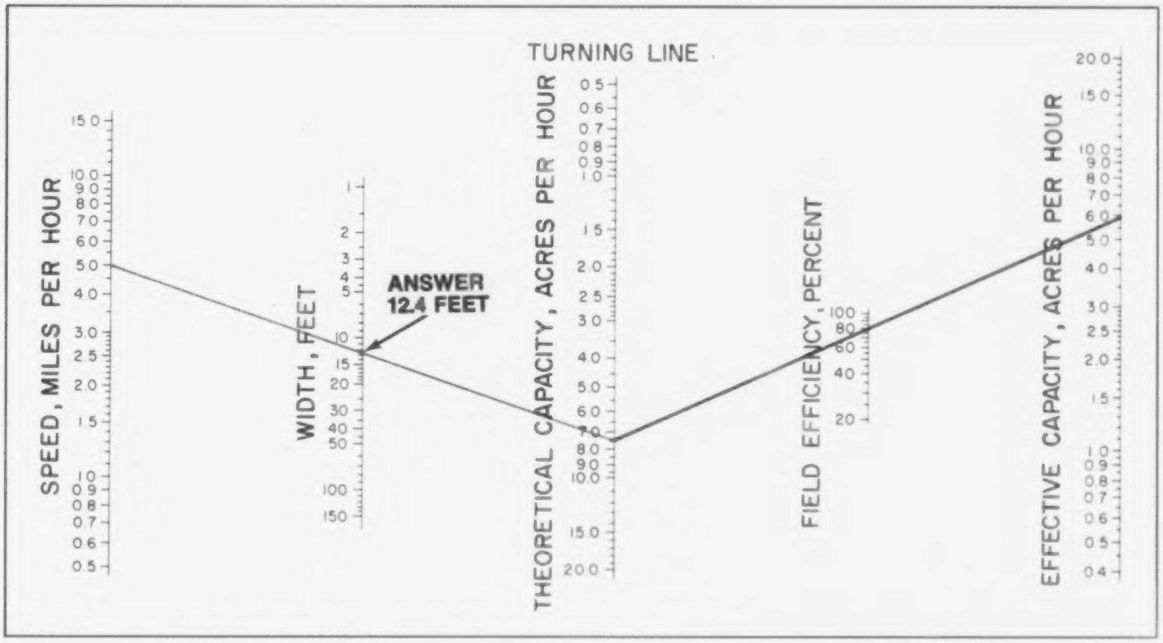
One of the best ways to determine how large a machine needs to be is to determine the necessary capacity to complete the operation within a specified calendar period (Fig. 11). The secret to success when using this method is to carefully select the calendar period and correctly estimate the number of hours you can work during that period.

FITTING CAPACITY TO TIME AVAILABLE

Let's take corn planting as an example of fitting capacity to the time available. How many calendar days do you consider to be the maximum for your situation? Five? Ten? Fifteen? Twenty? Be careful in allowing too many days. Corn needs a long growing season for maximum yields. Another important consideration is the average number of working hours in a day during the calendar period.

In this sample situation, assume a Midwestern corn grower with 280 acres of corn to plant wants to finish planting within a ten-calendar-day period. Considering weather and other delays typical of the

Fig. 10—Determining Needed Width With A Nomograph



TURNING LINE
SPEED, MILES PER HOUR
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.9
0.8
0.7
0.6
0.5
WIDTH, FEET
1
2
3
4
5
10
15
20
30
40
50
100
150
ANSWER 12.4 FEET
THEORETICAL CAPACITY, ACRES PER HOUR
0.5
0.6
0.7
0.8
0.9
1.0
1.5
2.0
2.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
15.0
20.0
FIELD EFFICIENCY, PERCENT
100
80
60
40
20
EFFECTIVE CAPACITY, ACRES PER HOUR
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4

Midwest, estimate an average of only four working hours per calendar day. How large a planter is needed, assuming a planting speed of 5.0 mph and 65 percent field efficiency? Use 30-inch row spacing for this example.

Solution:

Step 1. How many total hours are available?

Ten days at four hours per day equals 40 hours total.

Step 2. How much capacity in acres per hour would be needed?

$$\frac{280 \text{ acres}}{40 \text{ hours}} = 7.0 \text{ acres per hour}$$

Step 3. By formula,

$$\text{Width} = \frac{7.0 \times 8.25}{5 \times 0.65} = 17.77 \text{ feet} = 213 \text{ inches}$$

To find the number of 30-inch rows needed, divide the total planting width needed by the width of the row:

$$\frac{213 \text{ inches width}}{30 \text{ inches per row}} = 7.1 \text{ rows}$$

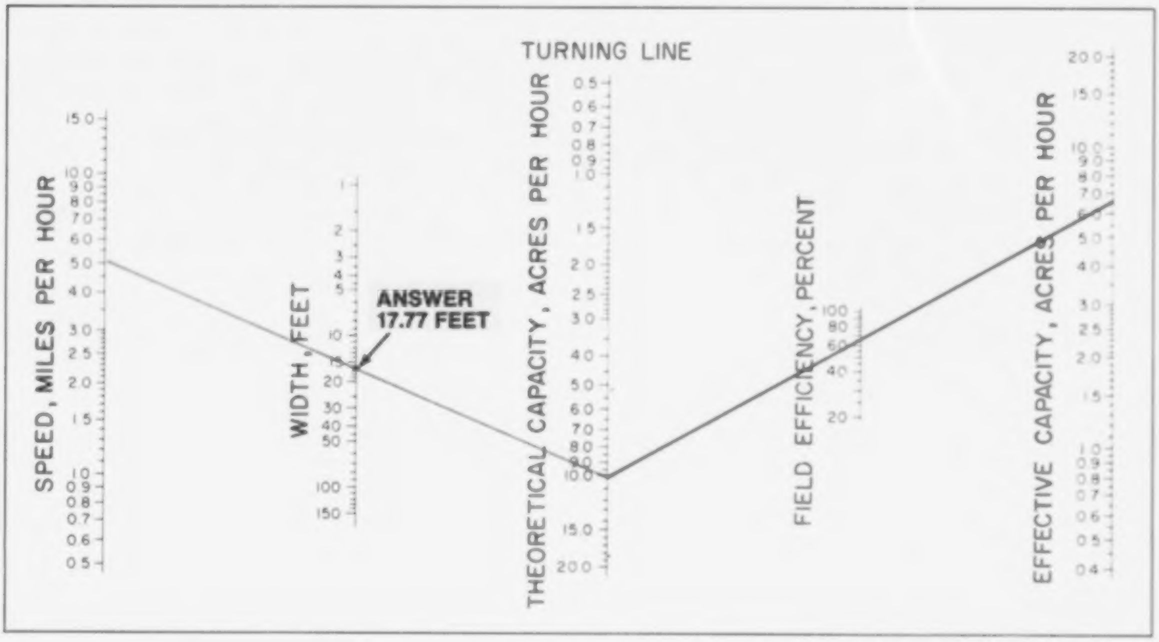
Answer: An 8-row, 30-inch planter would be needed.

Try solving the same problem using the nomograph in Figure 6. The solution is shown in Figure 12.

MAY
S M T W T F S
1 2 3 4
5 6 7 8 9 10 11
12 13 14 15 16 17 18
19 20 21 22 23 24 25
26 27 28 29 30 31

Fig. 11—Fitting Equipment Size To Available Working Time Is An Important Management Task

Fig. 12—In This Example, An 8-Row, 30-Inch (20 Ft.) Planter is Needed To Plant 7.0 Acres Per Hour



SUMMARY

Selecting the proper size machine to fit available time limits is a simple but effective method of getting important operations done on time. Keeping accurate records on days and hours of work will give you some valuable information after a few years (Fig. 13).

An alternate method to keeping records is consulting the county or area extension office for rainfall and temperature records. When just starting to compile records of working days, these type of records will help provide an average figure for planning.

Once the information on working days is gathered and organized, a chart similar to the one following can be helpful in planning operations.

SAMPLE WORKING DAYS CHART

Month	Fewest Days	Most Days	Average No. of Working Days
January	0	0	0
February	0	2	0
March	0	5	3
April	0	12	8
May	7	14	11
June	7	16	12
July	10	22	15
August	10	24	17
September	8	18	13
October	8	18	13
November	6	15	10
December	2	10	6

Note: *The above chart is only an example.* Keep your own records and make up your own chart or use the area average.

Fig. 14—Keep Records To Help Estimate Available Working Periods For Each Operation

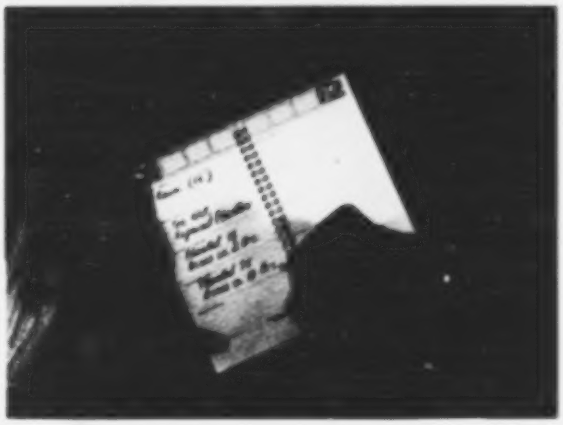


Fig. 13—Record Available Working Time For Important Operations For Later Use

Combining accurate records with the ability to accurately estimate effective field capacities will let you make valuable decisions on needed machine sizes. As a result you will soon realize a sizable reduction in "timeliness losses." *Your time will be well spent in keeping records to establish the average and minimum number of working days for critical field operations (Fig. 14).* In fact, your own records are the best accurate source of information on this subject.

The formulas for obtaining theoretical field capacity and effective field capacity that appear on page 31 may be used to obtain the same capacities in metric.

The formulas are as follows:

Ⓜ $$TFC = \frac{\text{Width, meters} \times \text{speed, km/h}}{10}$$

Example: A plow operates at a width of 2.03 meters and a speed of 7 kilometers per hour.

$$TFC = \frac{2.03 \times 7}{10} = 1.42 \text{ ha/hr}$$

Ⓜ $$EFC = TFC \times \frac{\text{Field Efficiency}}{100}$$

Example: Using a field efficiency of 85 percent with the above TFC

$$EFC = 1.42 \text{ ha/hr} \times \frac{85}{100} = 1.21 \text{ ha/hr}$$

Another example which correlates with the forage harvester example from page 32:

Windrower — 4.25 meter cutting width

Forage harvester speed — 6 km/h

Yield — 8000 kg/ha or 8 t/ha

Field Efficiency — 70 percent

Ⓜ $\text{TFC} = \frac{4.25 \times 6}{10} = 2.55$ ha/hr

2.55 ha/hr × 8 t/ha = 20.4 t/hr

Ⓜ $\text{EFC} = 20.4 \text{ t/hr} \times \frac{75}{100} = 14.3$ t/hr

A third example involves planter capacity. A comparable problem appears on page 33.

Planter — 6-row, 76-centimeter row spacing

Speed — 7.5 kilometers per hour

Field Efficiency — 60 percent

Ⓜ $\text{Width} = \frac{6 \text{ rows} \times 76 \text{ cm}}{100} = 4.6$ meters

Ⓜ $\text{TFC} = \frac{4.6 \times 7.5}{10} = 3.45$ ha/hr

Ⓜ $\text{EFC} = 3.45 \times \frac{60}{100} = 2.07$ ha/hr

Another example (comparable to the formula on page 35) is used to determine the width requirement for a disk

EFC — 2.5 ha/hr

Speed — 8 km/h

Field Efficiency — 80 percent

Ⓜ $\text{Width} = \frac{2.5 \text{ ha/hr}}{8 \text{ km/h}} \times 10 \times \frac{100}{80} = \frac{2500}{640} = 3.9$ meters

See the nomograph in the Appendix (page 168) used to determine needed width.

CHAPTER QUIZ

1. List two important reasons for selecting proper machine size.

2. Under what conditions can you actually operate a machine at its theoretical field capacity?

3. What is the theoretical capacity of a 6-row, 30-inch cultivator traveling 4.12 mph?

4. (Fill in blank.) The effective field capacity of a 14-foot offset disk with a field efficiency of 80 percent and operating at five miles per hour is
acres per hour.

5. You have 320 acres of wheat to combine in eight calendar days with an average of six working hours per day. What capacity in acres per hour will the combine have to average?

6. True or False? "Assuming an average speed of four miles per hour and a field efficiency of 70 percent, the minimum header width needed for the example in Question 5 is 19.6 feet."

7. A cotton field is yielding 1.5 bales per acre and is planted in 40-inch rows. What is the theoretical capacity in "bales per hour" of a 2-row harvester traveling three miles per hour? If its field efficiency is 55 percent what is the effective field capacity in bales per hour?

8. (Multiple choice.) What is the effective field capacity in tons per hour of a 2-row (40-inch rows), forage harvester if it travels four miles per hour and has a field efficiency of 60 percent? Yield is 15 tons per acre.

a. 29.1 tons per hour

b. 35.3 tons per hour

c. 48.5 tons per hour

9. (Multiple choice.) Theoretical capacity of a baler is five 70-pound bales per minute. If the field efficiency is 70 percent, what is the effective field capacity in tons per hour?

a. 10.5 tons per hour

b. 220.0 tons per hour

c. 7.35 tons per hour

10. (Multiple choice.) A corn combine averages 4,000 bushels in ten working hours. If the theoretical field capacity is six acres per hour and the yield is 100 bushels per acre, what is the field efficiency of the combine?

a. 82.5 percent

b. 66.7 percent

c. 60.0 percent

Ⓜ 11. (Multiple choice.) What is the effective field capacity in metric tons per hour of a 2-row (100-cm rows) forage harvester if it travels 6.5 km/h and has a field efficiency of 60 percent? Yield is 33.6 metric tons per hectare.

a. 47.4 t/hr

b. 26.2 t/hr

c. 35.3 t/hr

5
Estimating Power Requirements

Fig. 1—Equipment And Power Units Must Be Carefully Matched Regardless Of Size

INTRODUCTION

Now that we have discussed capacities of machines, let's turn our attention to selecting the power units that pull the machines.

A major task facing modern farmers and ranchers is to match power units to the size and type of machines so all field operations can be carried out on time with a minimum of cost.

When the amount of power of the power unit limits the size of equipment used with it, it is important to match them accurately (Fig. 1).

If the tractor is oversized for implements, the costs will be excessive for the work done. If the implements selected are too large for the tractor, the quality or quantity of the work may be lessened or the tractor will be overloaded, usually causing expensive breakdowns.

Some of the factors to consider when selecting a power unit include:

- **Engine type**
- **Power ratings**
- **Soil resistance to machines**
- **Tractor size**
- **Matching implements**
- **Sizing for critical work**

Let's look at each of these factors.

ENGINE TYPES

The three general types of engines currently in use include diesel, LP-Gas and gasoline. All three types are classified as internal combustion engines (Fig. 2). The diesel engine is a compression-ignition engine with only air being compressed in the cylinder. Diesel fuel is then injected into the cylinder and the fuel-air mixture is ignited by the heat of compression.

Fig. 2—Engines Convert Fuel To Mechanical Power

Gasoline and LP-Gas engines are spark-ignition engines. In both cases the fuel-air mixture is drawn into the cylinder and ignited by a spark.

The combustion process in the cylinders converts the energy contained in fuel to a rotating power source (Fig. 3). This rotating power can be further converted into three forms:

- **Drawbar Pull**
- **PTO Output**
- **Hydraulic System Output**

In some applications, like chopping forage, the power is used for pulling a load, operating a PTO shaft (Fig. 4), and raising and lowering the forage chopper head.

POWER RATINGS

Power is a measure of the rate at which work is being done. The English power unit is defined as 550 foot-pounds of work per second. The metric power unit is measured in kilowatts (kW). One kilowatt is equal to 1.34 horsepower. See end of chapter for metric equivalents.

If a load has enough weight and resistance to movement to require a force of 20 pounds to move it vertically a distance of three feet, the amount of work done is:

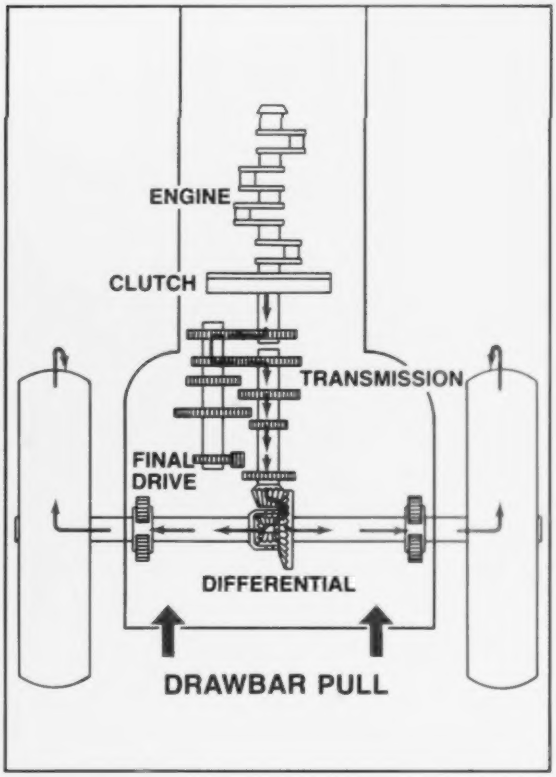
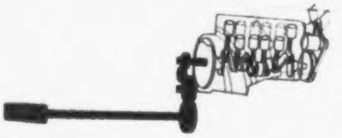


Fig. 3—Tractors Convert Rotating Power Of The Crankshaft To Drawbar Pull

Fig. 4—Tractors Also Convert The Rotary Motion Of The Crankshaft To The Output Of The PTO Shaft



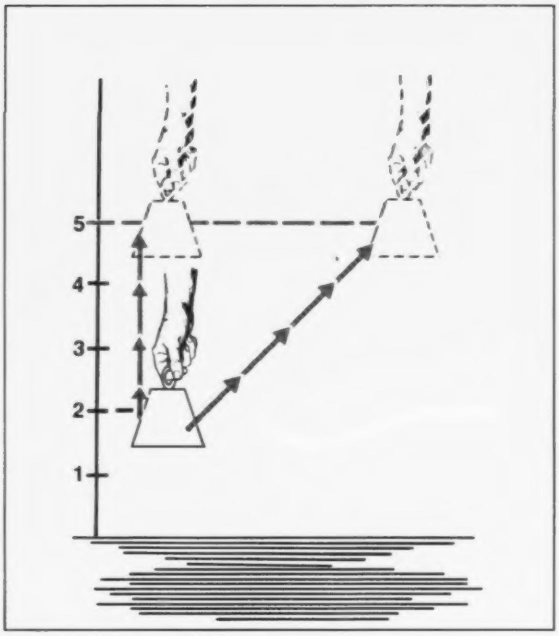


Fig. 5—Work Equals Force Times Distance Without A Time Factor

Work = force × distance (Fig. 5).

$$= 20 \text{ pounds} \times 3 \text{ feet} = 60 \text{ foot-pounds}$$

The amount of work done is 60 foot-pounds with no reference to time.

It wouldn't matter whether the time to move the load was one minute or one hour; the *amount* of work stays the same. When the *rate* of doing the work is considered, then power can be determined.

If a 1000-pound force is moved 33 feet in one minute, the rate of doing work is *one horsepower,* because one horsepower equals *33,000 foot-pounds per minute* (Fig. 6). The equivalent rate of work in one second to equal one horsepower is:

$$\text{One horsepower} = \frac{33{,}000 \text{ foot-pounds}}{60 \text{ seconds}}$$

$$= 550 \text{ foot-pounds per second}$$

When working with field machinery, we usually think of miles per hour and pounds of draft. For these conditions the formula for horsepower is:

$$\textbf{Horsepower} = \frac{\textbf{force, pounds} \times \textbf{speed, mph}}{\textbf{375}}$$

Ⓜ The formula for kilowatt appears on page 51.

EXAMPLE: If the draft of a trailing implement, like a disk harrow, is measured at 2500 pounds and is pulled at a speed of 5 mph, what is the drawbar horsepower (Fig. 7)?

$$\text{Drawbar Horsepower} = \frac{\text{force, pounds} \times \text{speed, mph}}{375}$$

$$= \frac{2500 \times 5}{375} = 33.3$$

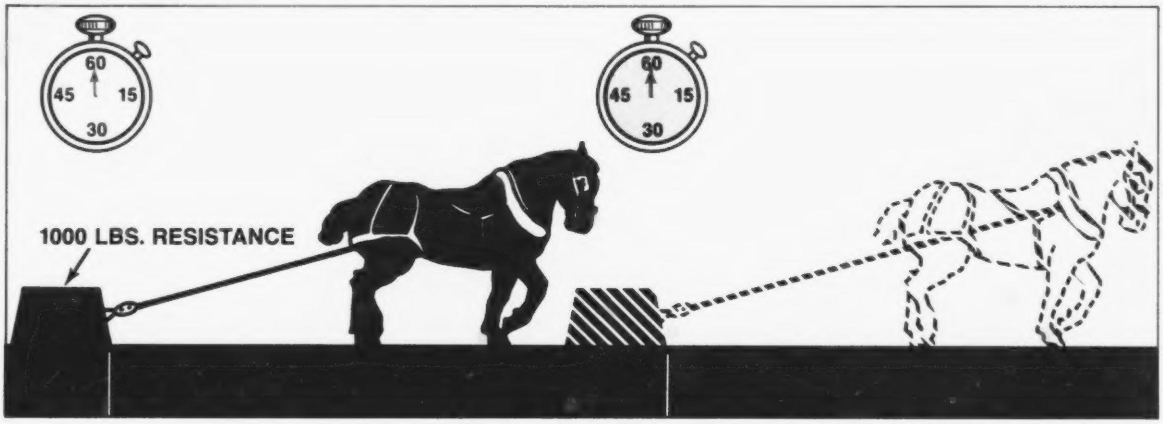
Notice we have used "drawbar" horsepower. Later in the chapter we will discuss how this relates to other kinds of horsepower, such as "PTO" and "engine" horsepower.

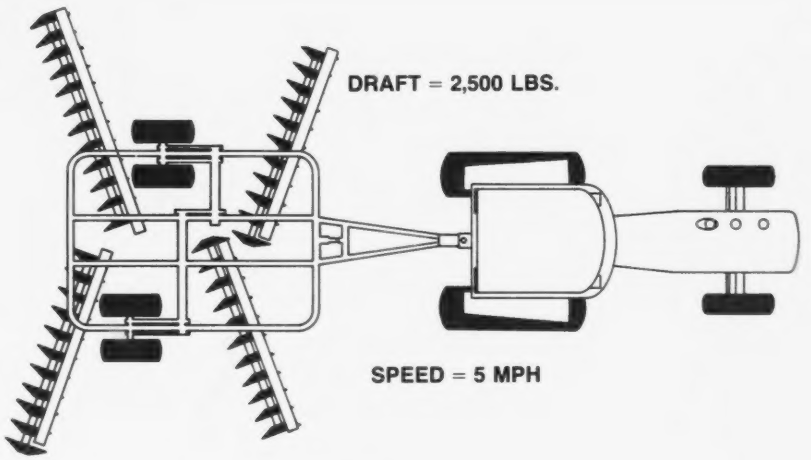
This formula can also be used to determine how fast an implement could be pulled with a given size of tractor (Fig. 8).

$$\textbf{Speed} = \frac{\textbf{drawbar horsepower} \times \textbf{375}}{\textbf{draft, pounds}}$$

EXAMPLE: A tractor is pulling a plow with a total draft of 5000 pounds. How fast can the plow be pulled if the tractor has 65 drawbar horsepower available?

Fig. 6—Horsepower Is A Measure Of The Rate At Which Work Is Done

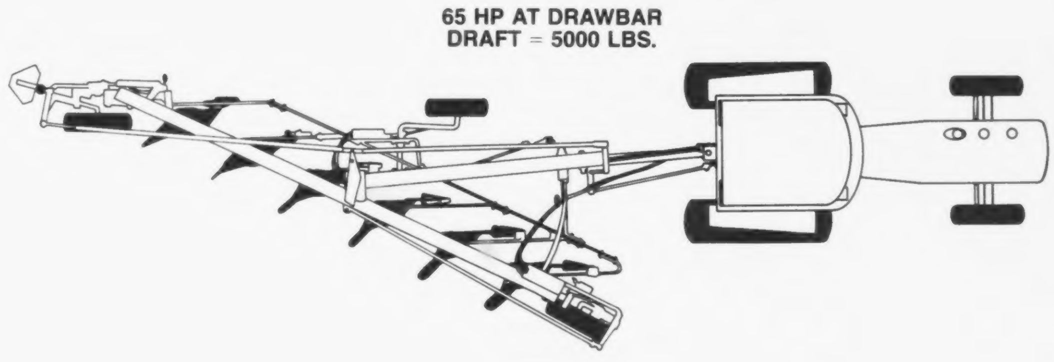



DRAFT = 2,500 LBS.
SPEED = 5 MPH

$$\text{DRAWBAR HP} = \frac{\text{DRAFT (LBS.) X SPEED (MPH)}}{375} = \frac{2500 \text{ X } 5}{375} = 33.3$$

Fig. 7—Drawbar Can Be Calculated If Draft And Speed Are Known

Fig. 8—You Can Calculate Speed If The Draft And Available Horsepower Are Known


65 HP AT DRAWBAR
DRAFT = 5000 LBS.

$$\text{SPEED} = \frac{\text{HP X } 375}{\text{DRAFT}} = \frac{65 \text{ X } 375}{5000} = 4.87 \text{ MPH}$$

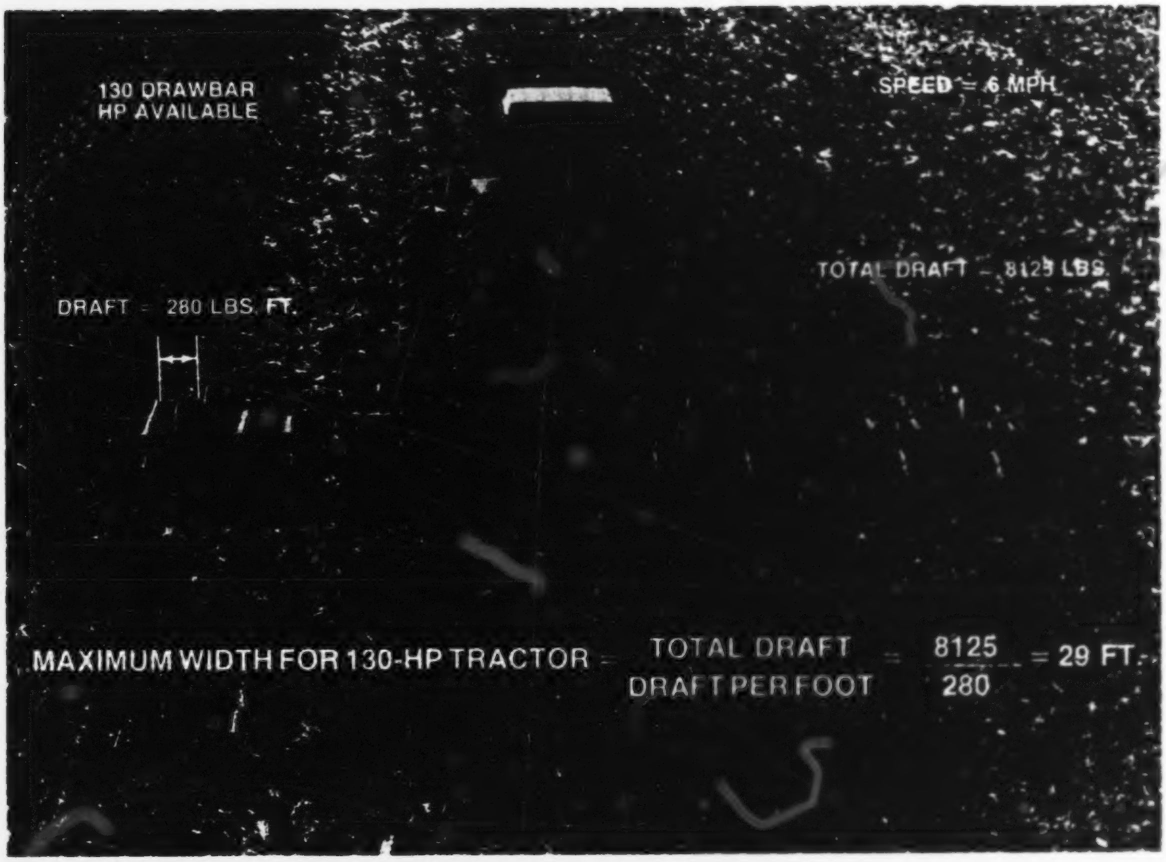

130 DRAWBAR
HP AVAILABLE
SPEED = 6 MPH
TOTAL DRAFT = 8125 LBS.
DRAFT = 280 LBS. FT.
MAXIMUM WIDTH FOR 130-HP TRACTOR = TOTAL DRAFT / DRAFT PER FOOT = 8125 / 280 = 29 FT.

Figure 9 — Determining Width Of Implement For A 130-HP Tractor

$$\text{Speed} = \frac{65 \times 375}{5000} = 4.87 \text{ mph}$$

This formula can also be used to determine how large an implement can be pulled, but an extra step or two is involved. In the first place, size of the implement would have to be related to the amount of soil resistance. This resistance is usually given as "pounds per foot" of width or "pounds per square inch". The latter is usually listed for moldboard plows.

EXAMPLE: A field cultivator is known to have a draft of 280 pounds per foot of width when used in a given field. A speed of 6 mph is desired. The available power unit has a 130 horsepower rating at the drawbar for continuous use. What width of field cultivator could be pulled (Fig. 9)?

Step 1. Determine maximum draft for 130 horsepower at 6 mph.

$$\text{Draft} = \frac{130 \times 375}{\text{speed, mph}} = \frac{130 \times 375}{6} = 8{,}125 \text{ pounds.}$$

Step 2. Determine width.

$$\text{Width, feet} = \frac{\text{total draft}}{\text{draft per foot}} = \frac{8125}{280} = 29 \text{ feet}$$

From a practical standpoint, we would probably select a 28- or 29-foot field cultivator.

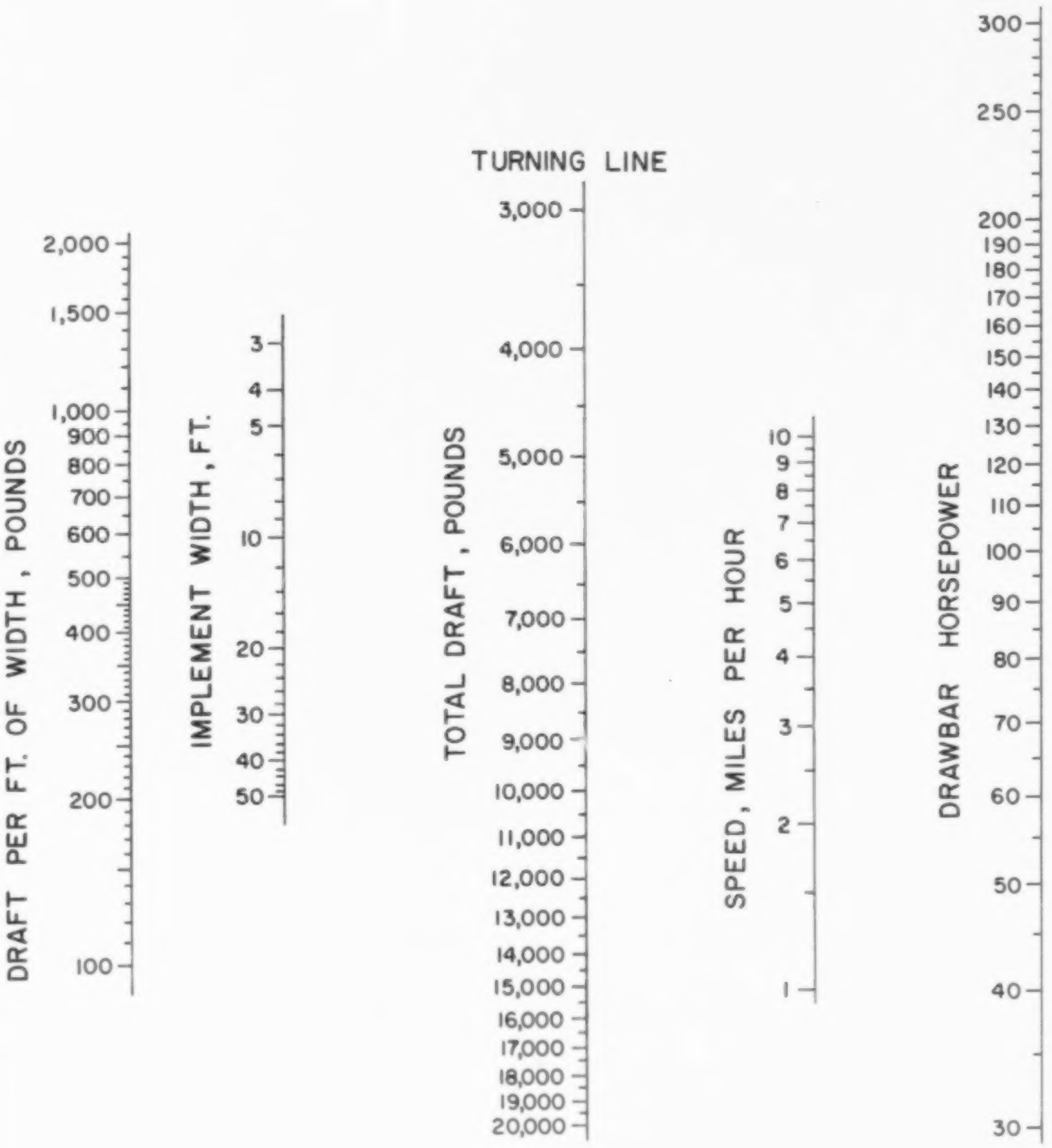
The nomograph in Figure 10 can be used to determine the required drawbar horsepower or to solve for any value not known, where all other values on the scale are either known or assumed. A comparable nomograph, calibrated in metric equivalents, appears on page 168, Appendix Table 10.

Let's use the same field cultivator as in the previous example to demonstrate how the nomograph works.

Notice there are four marked lines and one turning line on the nomograph. All we have to do to solve the problem is to draw two lines (Fig. 11).

Fig. 10—This Nomograph Can Be Used For Matching Implements And Tractors

DRAWBAR HORSEPOWER FOR TILLAGE TOOLS



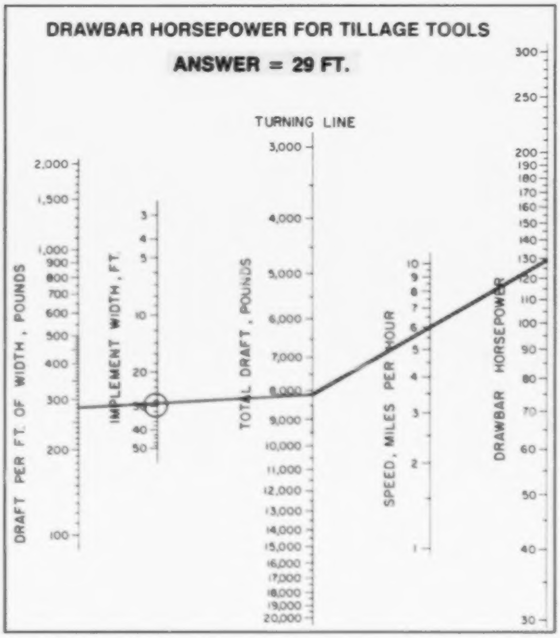


Fig. 11—By Drawing Two Straight Lines, The Problem Shown In Fig. 9 Can Be Solved

Start with 130 horsepower on the right-hand scale and draw a line through 6 mph until the turning line is intersected. Next draw a second line, starting at the point where the first line crossed the turning line. From this point draw a line through 280 pounds per foot on the far left scale. The second line crosses the width scale at 29 feet, the same answer given previously using the formula.

Fig. 12—How Much Drawbar Horsepower Would Be Needed To Pull A 16-Ft. Offset Disk At 4 MPH If Soil Resistance Is 400 Lbs./Ft.?

SPEED 4 MPH
WIDTH 16 FEET
DRAFT = 400 LBS. FT

CALCULATING MACHINE SOIL RESISTANCE

In order to use the nomograph for selecting power units, it is necessary to know the soil resistance for various machines. The Soil Resistance Table, adapted from the Agricultural Engineering Yearbook, lists some unit draft ranges for those implements having the highest power requirements per foot of width. The table also shows the horsepower required per foot of width at a typical field speed for the middle of the draft range. See Appendix, page 169 Table 11 with metric equivalents.

TABLE 1

SOIL RESISTANCE

Operation	Pounds of Draft/ Foot of Width	Typical Speed, mph	Drawbar Horsepower per Foot of Width
PLOWING (8 INCHES DEEP)			
Gumbo	1250	4.0	13.3
Clay	1050	4.0	11.2
Loam	950	4.5	11.4
Sandy Loam	700	5.0	9.3
Sand	350	5.0	4.7
CHISEL PLOWING (8 INCHES DEEP)			
Hard, Dry	800	4.0	8.5
Medium Clay Loam, Good Moisture	500	5.0	6.7
Sand, Sandy Loam	200	6.0	3.2
FIELD CULTIVATOR			
Heavy Clay Soils or Dry and Hard Conditions	650	4.0	6.9
Clay Loam	450	5.0	6.0
Sandy Loam	300	5.0	4.0
Sand	150	6.0	2.4
TANDEM DISK HARROW			
Heavy Draft	300	4.0	3.2
Medium Draft	200	5.0	2.7
Light Draft	100	6.0	1.6
OFFSET OR HEAVY TANDEM DISK			
Heavy Draft	400	4.0	4.3
Medium Draft	325	5.0	4.3
Light Draft	250	6.0	4.0
ONE-WAY DISK			
Heavy Draft	400	4.0	4.3
Medium Draft	300	5.0	4.0
Light Draft	200	6.0	3.2

The table can be used directly to determine required drawbar power, or it can be used with the nomograph. Let's try an example.

For the sample problem, we want to determine how much drawbar horsepower is required to pull a 16-foot, heavy-duty, offset disk harrow (Fig. 12)? Table 1 shows a typical speed of five mph for medium draft but only four mph for heavy draft. This difference occurs because in most tillage operations, draft increases with speed.

It is good management to size power units for conditions of slower field speeds used in extremely high draft conditions. By doing this, power units are sized for maximum loads that might be encountered. In this way, a tractor can be used over a wide range of soil conditions simply by changing field speed.

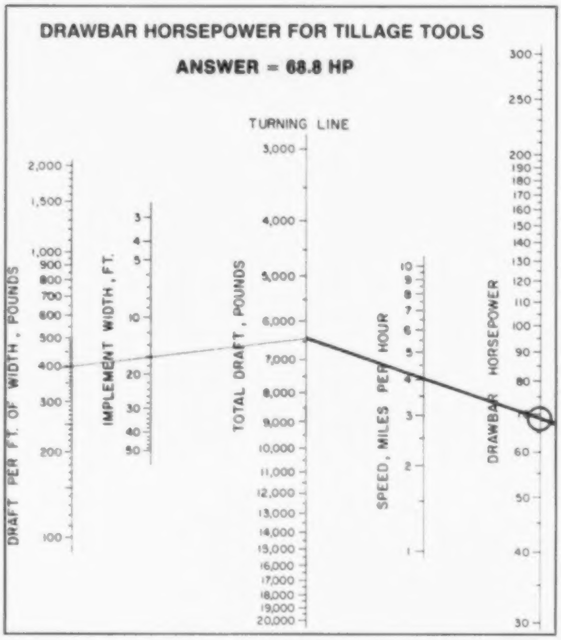
Going back to the sample problem, Table 1 shows a draft of 400 pounds per foot at four mph and 4.3 drawbar horsepower per foot of width. Multiplying total width by horsepower per foot gives total horsepower required:

16 ft. × 4.3 horsepower per foot = 68.8 drawbar hp

Using the nomograph, as shown in Figure 13, also gives an answer of 68.8 drawbar horsepower.

The table could also be used to determine how large an implement could be pulled with a given size of tractor. Suppose you have a tractor with 85 usable drawbar horsepower. How large a plow will it pull in a loam soil?

Fig. 13—The Second Line Intersects The Right-Hand Scale At 68.8 HP



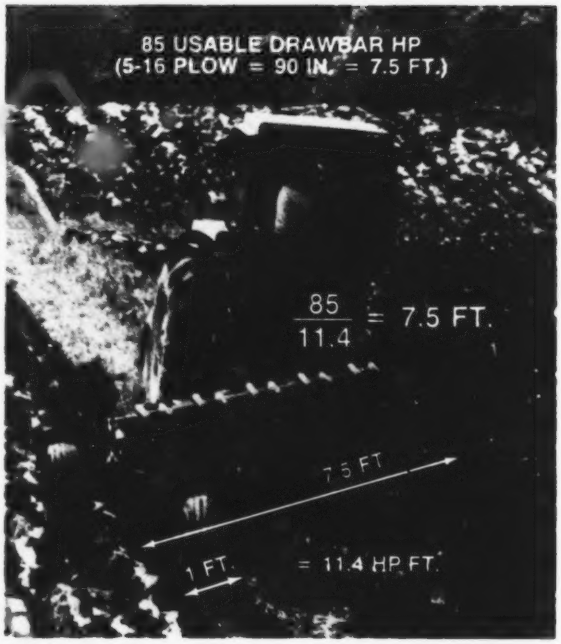


Fig. 14—At 11.4 Horsepower Per Foot, 85 Usable Drawbar HP Could Pull 5-16's

The table shows 11.4 horsepower per foot of width. Dividing 85 by 11.4, we get 7.5 feet of width (Fig. 14).

7.5 × 12 inches = 90 inches

Thus, it would pull either a 5-furrow, 18-inch plow; or 5-furrow, 16-inch plow; or a 6-furrow, 14-inch plow. The table is intended only as a *guide*, as draft for various tools and soil conditions is highly variable.

DETERMINING TRACTOR SIZE NEEDED

Even when it is known how much power is needed for a given field operation, knowing the size of tractor to use still presents a problem.

First, there are several different kinds of power measurements, all applying to the same tractor. For a better understanding of the drawbar-power and tractor-size relationship, let's start at the engine and define the various kinds of power:

- **Brake**
- **PTO**
- **Drawbar**

Remember, tractor power is measured in horsepower (the customary measurement in the U.S.A.) or in kilowatts (the metric equivalent). In the following discussion we will use the U.S. customary terminology.

FLYWHEEL OR BRAKE HORSEPOWER (B.H.P.)

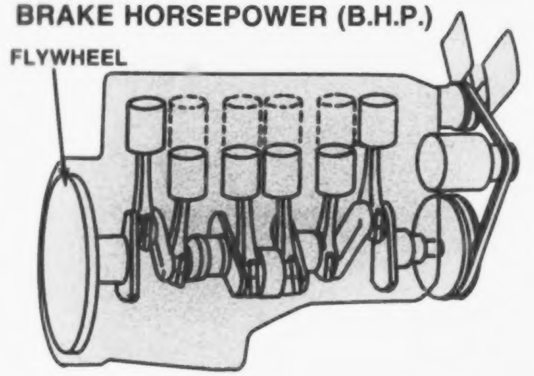


Fig. 15—Brake Horsepower Is A Measurement Of The Power Developed At The Flywheel

Let's discuss these different kinds of power in more detail.

BRAKE HORSEPOWER is the maximum power the engine can develop without alterations. The engine, before installation in a tractor, can be hooked to a dynamometer to determine how much brake horsepower can be developed (Fig. 15). This figure is particularly useful in sizing stationary engines for operating irrigation pumps, grinders, and other equipment. The same engines used for large tractors are often used as stationary engines.

POWER TAKEOFF HORSEPOWER, PTO hp in short, is the power measured at the PTO shaft (Fig. 16).

DRAWBAR HORSEPOWER is a measure of the pulling power of the engine by way of tracks, wheels or tires. As a percentage of PTO horsepower, the drawbar horsepower varies, depending widely, on several factors including soil surface and type of hitch. As seen earlier, drawbar horsepower is a function of drawbar pull and speed.

Of the various kinds of horsepower, *maximum PTO hp* is the one most commonly used in designating the size of a tractor (Fig. 17). An exception is some of the large 4-wheel-drive tractors that do not have a PTO shaft. They may be given a *brake hp* (flywheel) or *maximum drawbar hp* rating. Know these definitions for comparing tractors when buying.

So the problem really becomes one of knowing how much horsepower any given tractor will have available for constant use on the drawbar. This problem is further complicated by different kinds of soil conditions. The less firm the soil, the more horsepower lost at the drawbar. Speed, tire size, slippage and ballasting are all important factors in obtaining the best operating conditions for a specific situation.

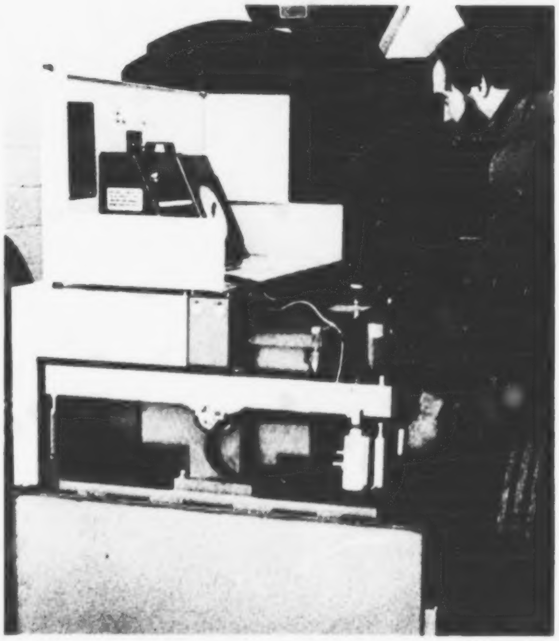


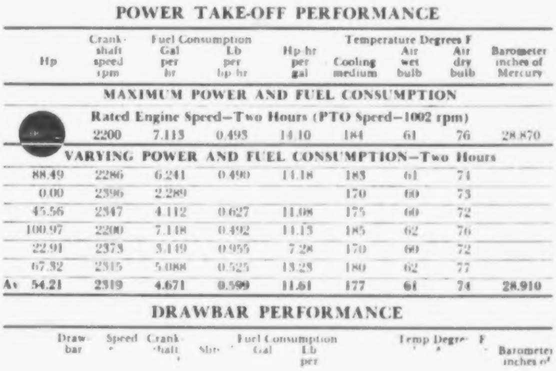
Fig. 16—PTO hp Being Measured By A Shop Dynamometer

A tractor must be sized for the job. On farms with one principal field tractor, that job is usually primary tillage. In the Corn Belt, moldboard plows may be the highest draft implements.

In the Corn Belt, speed and depth of plowing are the main contributors to draft. Farther west where large farmland areas require high productivity, width becomes the principle draft variable with speed a close second.

By sizing the principal tractor for primary tillage, planting, cultivating, and other operations, it will be

Fig. 17—Maximum PTO hp Is The Most Commonly Used Method To Rate Tractor Power



POWER TAKE-OFF PERFORMANCE

Hp	Crank-shaft speed rpm	Fuel Consumption Gal per hr	Fuel Consumption Lb per hp-hr	Hp-hr per gal	Temperature Degrees F Cooling medium	Temperature Degrees F Air wet bulb	Temperature Degrees F Air dry bulb	Barometer inches of Mercury
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—1002 rpm)								
[illegible]	2200	7.113	0.493	14.10	184	61	76	28.870
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
88.49	2286	6.241	0.490	14.18	183	61	74	
0.00	2396	2.289			170	60	73	
45.56	2347	4.112	0.627	11.08	175	60	72	
100.97	2200	7.148	0.492	14.13	185	62	76	
22.91	2373	3.149	0.955	7.28	170	60	72	
67.32	2315	5.088	0.525	13.23	180	62	77	
Av 54.21	2319	4.671	0.599	11.61	177	61	74	28.910

DRAWBAR PERFORMANCE

Draw-bar	Speed	Crank-shaft	Slip	Fuel Consumption Gal	Fuel Consumption Lb per	Temp Degrees F			Barometer inches of

R P M IN HUNDREDS
5
10
15
20
25
SEE MANUAL FOR SPEEDS
MILES PER HOUR
10
HI
10376

Fig. 18—In Matching Tractors And Heavy-Draft Implements, It Is Important To Avoid Engine Overloading

overpowered for some operations but, more *importantly*, all operations will get done on time.

While the exact procedure for determining available drawbar horsepower for a specific tractor and a set of conditions is very complicated, we can provide some useful guidelines based on practical field experiences.

MATCHING TRACTORS AND IMPLEMENTS

When matching a tractor and implement, three important factors must be considered:

1. The tractor must not be overloaded or early failure of components will occur (Fig. 18).

2. The implement must be pulled at the proper speed or optimum performance cannot be obtained (Fig. 19).

3. The soil conditions and their effects on machine performance must be considered.

Fig. 19—Match Implements To Tractors So Proper Speed Is Maintained—Usually 4 MPH Or More

With a given tractor, there is a set amount of power available. This available power is used for:

1. *Moving the tractor over the ground*
2. *Pulling the implement over the ground*
3. *Powering the implement for useful work*

The softer or looser the soil conditions are, the greater the amount of power that will be consumed because of greater rolling resistance. This reduces the available usable drawbar power (Fig. 20).

Table 2 is a sample for setting up a chart that can be used to *estimate* the usable drawbar horsepower and the ratio of maximum horsepower to usable drawbar horsepower for various soil conditions.

TABLE 2

SOIL CONDITIONS—POWER

Condition Of Soil	Usable Drawbar Power As A Percentage Of Maximum PTO Power*	Ratio Of Maximum PTO Power To Usable Drawbar Power
Firm	**67 Percent**	**1.5**
Tilled	**56 Percent**	**1.8**
Soft or Sandy	**48 Percent**	**2.1**

*If tractor does not have a maximum PTO power rating, use an assumed rating equal to 86 percent of maximum engine power.

This table is based on properly ballasted two-wheel-drive tractors. In severe traction conditions (soft or sandy soil) front wheel assist four-wheel-drive tractors have an estimated 5% to 10% more drawbar pull than two-wheel-drive tractors. Under the same conditions, the full four-wheel-drive tractor with all wheels of equal size will have approximately 15 percent greater drawbar pull. Proper ballasting and sizing of matching equipment to control wheel slippage is a must with any power unit.

It is sometimes helpful to know the ratio of maximum PTO hp to usable drawbar hp. The ratio figures in Table 2 can be used to make it easier to calculate needed maximum PTO hp when the drawbar hp required by an implement is known.

If an implement like a plow is to be used on firm soil, the required drawbar horsepower would need to be multiplied times 1.5 to obtain maximum PTO horsepower. But if the surface has been tilled, the PTO horsepower would be 1.8 times the required drawbar horsepower.

Suppose it is desired to find how large a tractor is needed to pull a 5-furrow, 16-inch plow in a medium-to-heavy soil with surface conditions considered as firm. Information in Table 1 shows 13.3 hp per foot for gumbo and 11.2 hp per foot for clay. We will use 12 drawbar horsepower per foot as an average.

$$\text{Plow width (5-16's)} = \frac{80 \text{ inches}}{12 \text{ inches}} = 6.7 \text{ feet}$$

$6.7 \text{ feet} \times 12 \text{ hp per foot} = 80 \text{ drawbar hp needed}$

For a firm soil, multiply drawbar horsepower times 1.5 to obtain the required *rated PTO hp.*

$80 \times 1.5 = 120$ PTO horsepower required

See pages 51 and 52 for metric equivalents to these formulas.

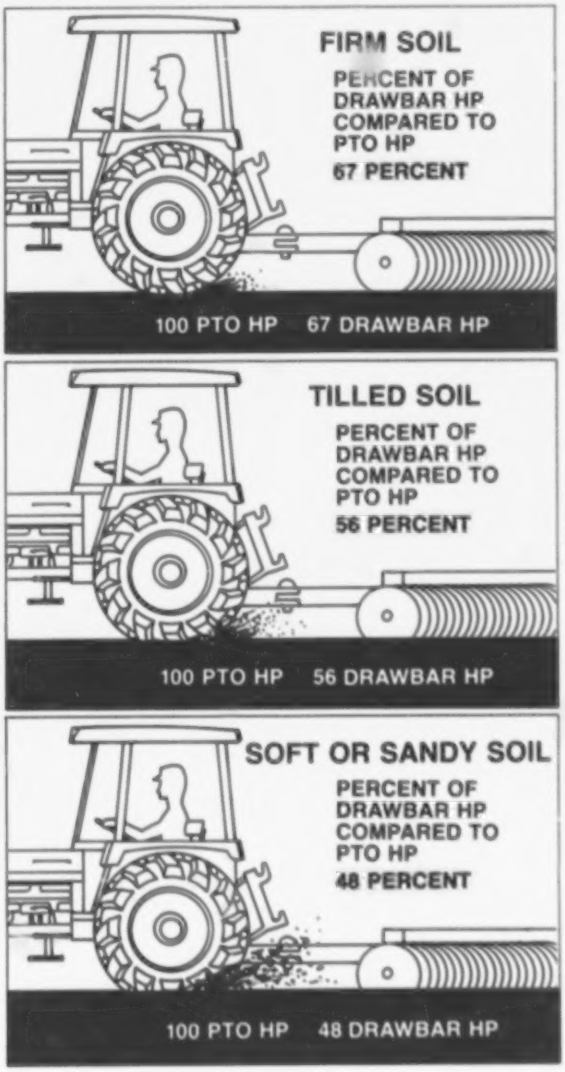
If the tractor size is known, and it is needed to know how large an implement can be pulled, the answer can be found using almost the same procedure.

EXAMPLE: How large of a heavy offset disk can be pulled by a tractor rated at 145 maximum PTO hp? Speed is assumed to be five mph, soil conditions are firm, and draft is 400 pounds per foot of width.

Usable drawbar hp = 67 percent of maximum PTO hp

$$= .67 \times 145 = 97.15 \text{ hp}$$

Fig. 20—As Softer Soil Conditions Are Encountered, Usable Drawbar Horsepower As A Percentage Of Maximum Rated PTO HP Becomes Less


FIRM SOIL
PERCENT OF DRAWBAR HP COMPARED TO PTO HP
67 PERCENT
100 PTO HP 67 DRAWBAR HP
TILLED SOIL
PERCENT OF DRAWBAR HP COMPARED TO PTO HP
56 PERCENT
100 PTO HP 56 DRAWBAR HP
SOFT OR SANDY SOIL
PERCENT OF DRAWBAR HP COMPARED TO PTO HP
48 PERCENT
100 PTO HP 48 DRAWBAR HP

$$\text{Width} = \frac{\text{usable drawbar hp} \times 375}{\text{speed, mph} \times \text{draft, per foot}}$$

$$= \frac{97.15 \times 375}{5 \times 400} = \frac{36,750}{2,000} = 18.22 \text{ feet}$$

Also, solve this problem using the nomograph (Fig. 21). The maximum-width disk that could be pulled for this situation would be 18.22 feet. In all probability a 16- to 17-foot disk would be bought to have a margin for power requirements.

SIZING POWER UNITS FOR CRITICAL WORK PERIODS

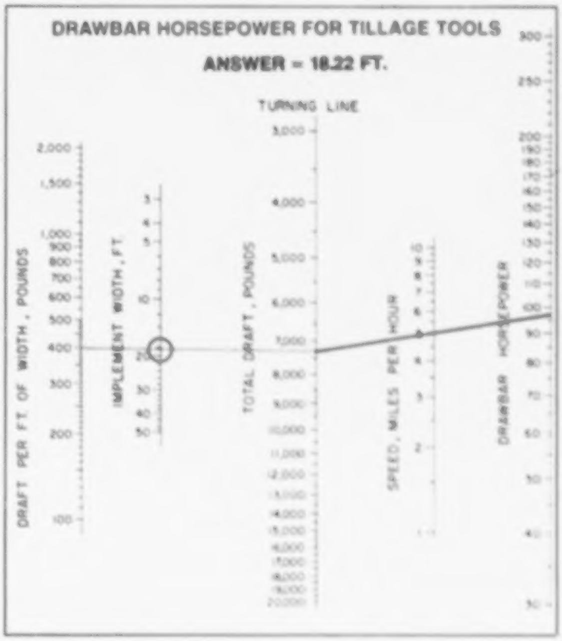
In Chapter 4 we discussed matching machine size to fit time available. An important management task is to properly match power units to these machines.

Let's take an example using a typical Corn Belt situation in which we want to select a plow and tractor. Suppose your records show the following:

SAMPLE RECORD OF WORKING TIME

Month	Calendar Days	Average Working Days	Average Total Working Hours/Month
October	31	18	96
November	30	15	75
March	31	14	70
April	30	16	96
	122	63	337

Fig. 21—Using Nomograph To Determine Size Of Offset Disk



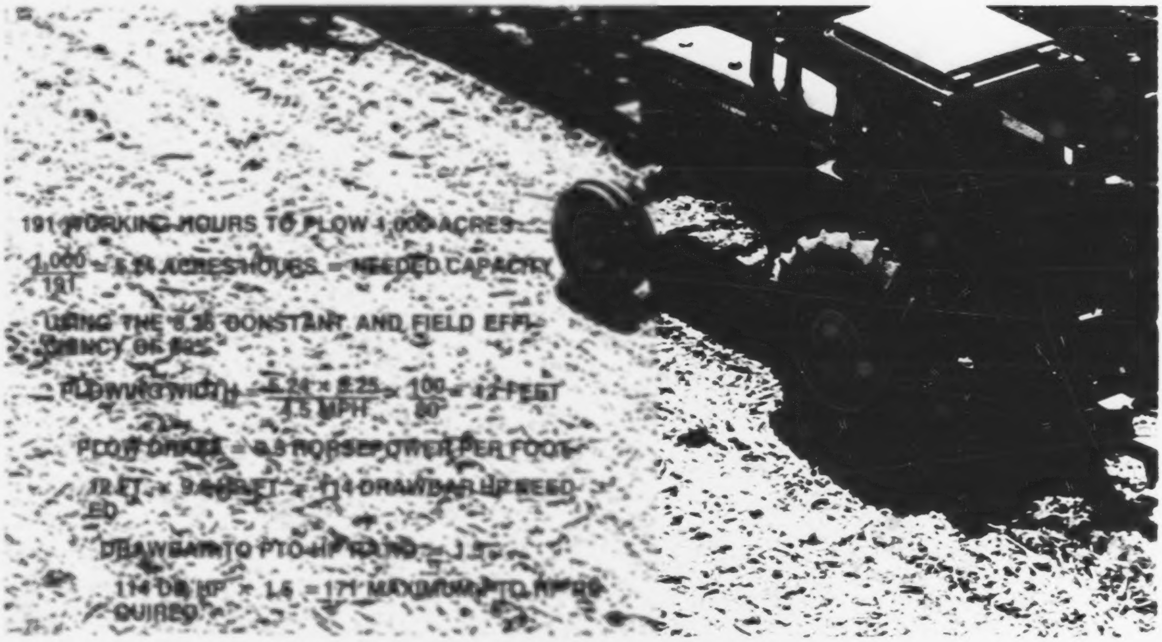

191 WORKING HOURS TO PLOW 1,000 ACRES
$\frac{1,000}{191}$ = 5.24 ACRES/HOURS = NEEDED CAPACITY
USING THE 8.25 CONSTANT AND FIELD EFFICIENCY OF 80%
PLOWING WIDTH = $\frac{5.24 \times 8.25}{4.5 \text{ MPH}} \times \frac{100}{80}$ = 12 FEET
PLOW DRAFT = 9.5 HORSEPOWER PER FOOT
12 FT. × 9.5 HP/FT = 114 DRAWBAR HP NEEDED
DRAWBAR TO PTO HP RATIO = 1.5
114 DB HP × 1.5 = 171 MAXIMUM PTO HP REQUIRED

Fig. 22—Example Of How To Match Implement Size And Tractor To Available Working Time

Do not base machinery selection on average weather conditions because weather conditions will vary from year to year. Suppose that in your farming location a maximum of 225 working hours are available in the years of the poorest weather conditions. This means sizing the tractor and plow for 225 working hours.

Even then, don't count on keeping a tractor and plow operating continuously. Some experts say at the best, 85 percent of available working time is spent in the field. This further reduces actual working time to 85 percent of 225 hours or a total of 191 hours.

For example, if you plow 1000 acres every year in a light clay loam with firm tractive conditions, how large a tractor and plow would be needed?

To plow 1000 acres in 191 hours, a capacity of 5.24 acres per hour would be needed. Assuming an 80 percent field efficiency and a plowing speed of 4.5 miles per hour, the size of the plow would be:

$$\text{EFC} = \frac{\text{Speed} \times \text{Width}}{8.25} \times \frac{\text{E, field efficiency}}{100}$$

$$\text{Thus, width} = \frac{8.25 \times \text{Capacity}}{\text{Speed}} \times \frac{100}{\text{E}}$$

$$= \frac{8.25 \times 5.24}{4.5} \times \frac{100}{80} = 12 \text{ feet}$$

$$= 144 \text{ inches}$$

A plow with nine, 16-inch bottoms would plow a width of *144 inches*.

Our table for plow draft indicates about 9.5 horsepower per foot should be used. To calculate drawbar horsepower, multiply the horsepower per foot by the width of the implement:

9.5 × 12 = 114 drawbar hp

Because it is firm soil, the ratio is 1.5 (Table 2).

114 drawbar hp × 1.5 = 171 PTO horsepower needed (Fig. 22).

METRIC EQUIVALENTS

The metric unit for power is kilowatt.

Force is measured in newtons or kilonewtons.

1 hp = 0.746 kW; 1 kW = 1.34 hp

1 kN = 224.8 pounds force; 1 N = 0.225 pounds

The formula for kilowatt is:

$$\text{kW} = \frac{\textbf{force, kilonewtons} \times \textbf{speed, km/h}}{\textbf{3.6}}$$

Example: If the draft of a trailing implement, such as a disk harrow, is measured at 11.1 kilonewtons and is pulled at a speed of 8 kilometers per hour, what is the drawbar kilowatt?

$$\textbf{Drawbar kilowatt} = \frac{\textbf{11.1 kN} \times \textbf{8 km/h}}{\textbf{3.6}} = \textbf{24.7 kW}$$

The formula can also be used to determine speed.

Example: A tractor is pulling a plow with a total draft of 22.2 kilonewtons. How fast can the plow be pulled if the tractor has 50 drawbar kilowatts?

$$\text{Speed} = \frac{50\text{ kW} \times 3.6}{22.2\text{ kN}} = 8.1\text{ km/h}$$

The formula to determine draft is:

$$\text{Draft} = \frac{\text{power, kilowatt} \times 3.6}{\text{speed, km/h}}$$

Example: 65 kW tractor

Speed — 8 km/h

Field cultivator draft is 4 kN per meter of width when used in a given field.

What width of cultivator could be pulled?

Ⓜ Step 1: $\text{Draft} = \frac{65\text{ kW} \times 3.6}{8\text{ km/h}} = 29.25\text{ kN}$

Ⓜ Step 2: $\text{Width, meters} = \frac{\text{total draft}}{\text{draft per meter}} =$

$$\frac{29.25}{4} = 7.3\text{ meters}$$

We would probably select a field cultivator about 7 meters wide.

Metric equivalents to equations on page 50 are:

A 5-bottom, 40-cm plow operates in medium to heavy soil with surface conditions considered as firm. Information from Table 9 on page 168 shows 32.5 drawbar kW per meter of width for gumbo and 27.4 kW per meter for clay. We will use 30 drawbar kW per meter as the average.

Ⓜ Plow width $(5 \times 40) = \frac{200}{100} = 2$ meters

2 meters × 30 kW per meter = 60 drawbar kW needed

If tractor size is known, determine how large an implement can be pulled.

Tractor size — 110 PTO kW

Speed — 8 km/h

Soil condition — firm

Draft — 5.83 kN per meter of width

Usable drawbar kW — 67 percent of maximum

PTO kW = .67 × 110 = 73.7 kN

$$\text{Width} = \frac{73.7\text{ kW} \times 3.6}{8 \times 5.83} = 5.7\text{ meters}$$

SUMMARY

Remember that when matching implements and tractors, a margin for error is needed for variations in field conditions. The tables given in this chapter are intended only as guidelines. Use your own figures where possible.

Alternatives to oversizing equipment for years with fewer working days include hiring custom operators or leasing machinery. These options will be discussed in later chapters.

CHAPTER QUIZ

1. How much work is done in lifting a 100-pound weight a distance of 30 inches?

2. What drawbar horsepower is required to pull a disk with a total draft of 4000 pounds at a speed of 5 mph?

a) 80 hp

b) 56 hp

c) 53.3 hp

3. How fast could you pull a 10,000 pound load with a tractor that has 100 usable drawbar horsepower?

a) 3.75 mph

b) 5.62 mph

c) 6.75 mph

4. A tractor using 60 drawbar horsepower is pulling an 18-foot tandem disk at a speed of 5 mph. What is the draft per foot of width for the disk?

a) 375 pounds/ft.

b) 250 pounds/ft.

c) 2500 pounds/ft.

5. A tractor has a rating of 150 maximum PTO hp. What would be the maximum amount of usable hp for each of the three soil conditions—Firm? Tilled? Soft?

6. A chisel-plow is to be used in heavy soil conditions where the resistance is 600 pounds per foot of width. Soil condition is considered firm. What size tractor would be needed to pull the chisel at a speed of 4 mph if the chisel is 12 feet wide?

7. You have a tractor rated at 100 maximum PTO hp and want to buy a moldboard plow. You will plow 8-inches deep with most of the soil being a loam. What size plow would you buy? Assume firm conditions for the tractor.

8. You have 400 acres of land to prepare for wheat seeding and must go over the tilled ground twice in 16 working days with a tillage tool that has 300 pounds of soil resistance per foot. Assuming it needs to be pulled at 5 mph, what size tool and tractor would be needed? For each working day you can average 8 hours in the field and field efficiency is 80 percent.

9. Why does it require more horsepower in soft soil to pull the same implement than in firm soil?

II

Estimating Machinery Costs

Estimating Fixed Costs 6
Estimating Fuel and Lubricant Costs 7
Estimating Repair Costs 8
Total Costs For Machines and Operations 9

ESTIMATING MACHINERY COSTS

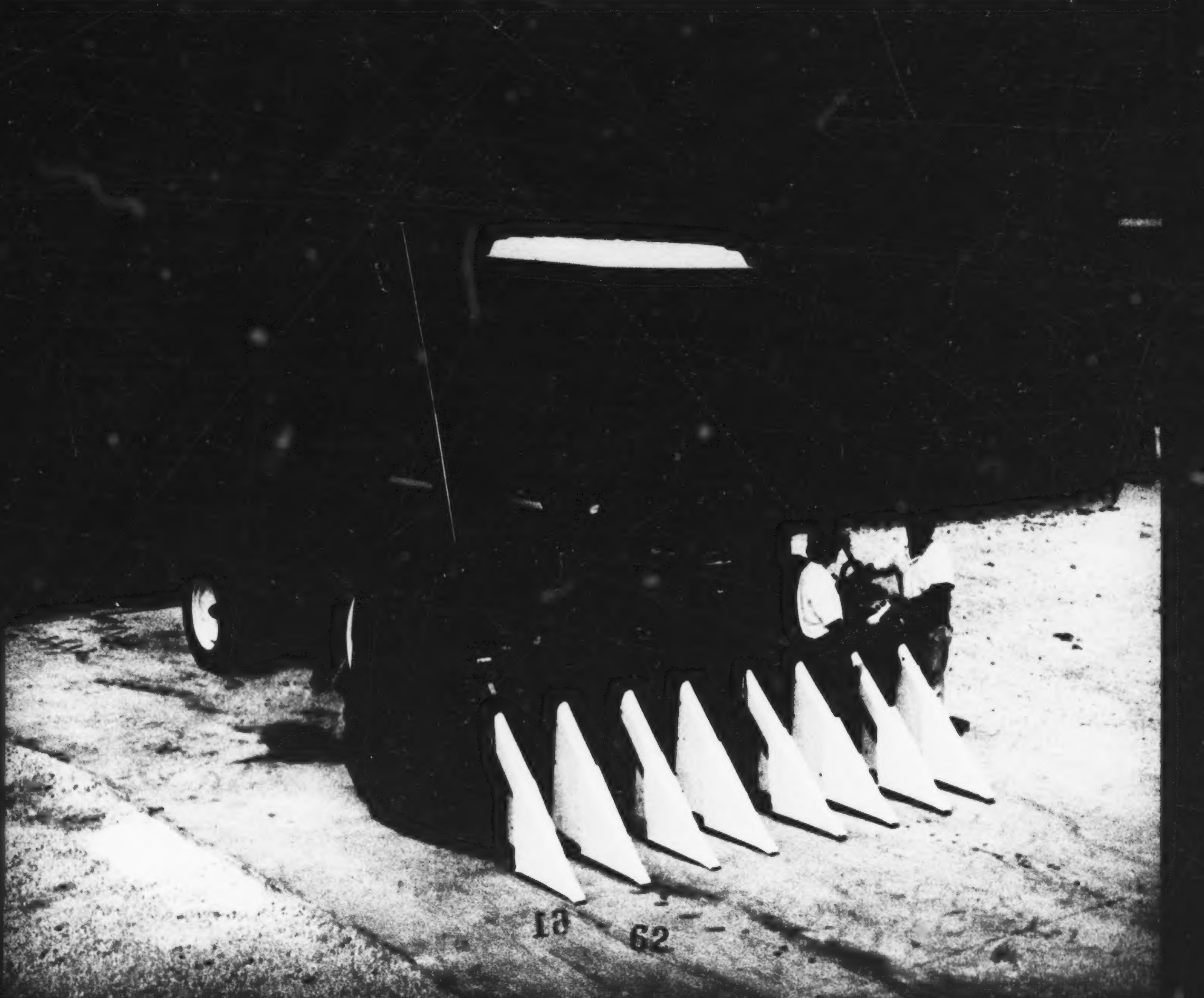
Knowing how to accurately estimate costs for owning and operating farm machinery is an important step to becoming a top-notch manager. Once you know how to estimate costs, it will be much easier to come up with those profit-making decisions.

This section of Machinery Management provides information on how to estimate fixed costs, operating costs and total costs for any machine, according to its initial cost and annual use.

This second section, along with Section I, will complete coverage of the basic information needed to make the machinery management decisions to be discussed in Section III.

6

Estimating Fixed Costs



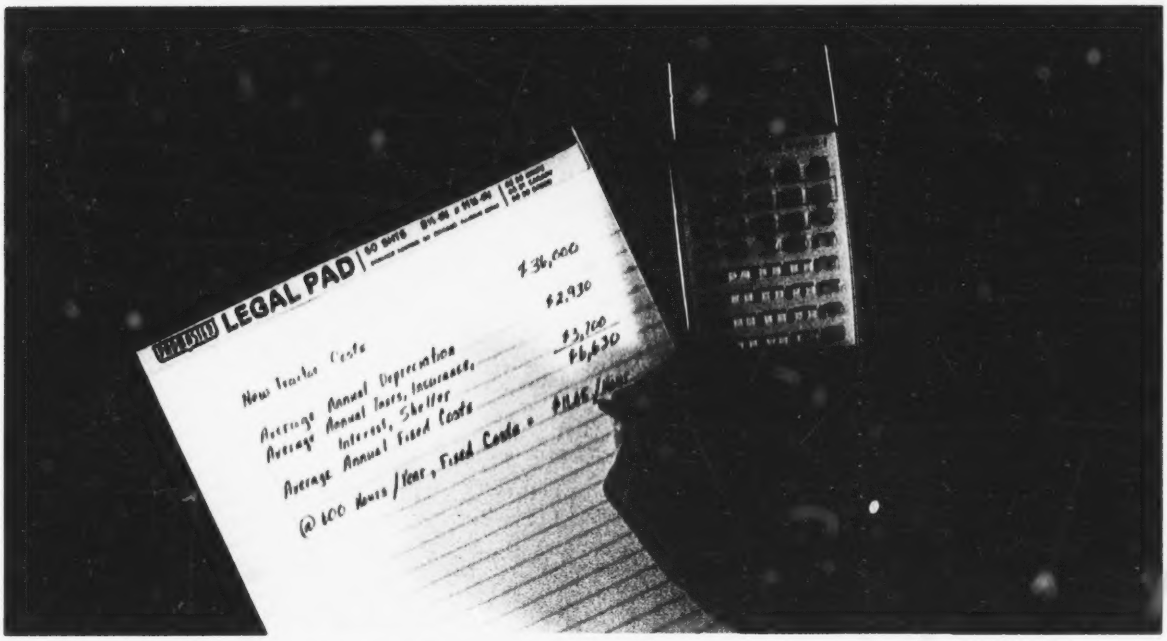

LEGAL PAD
New Tractor Costs $36,000
Average Annual Depreciation $2,930
Average Annual Taxes, Insurance, Interest, Shelter $3,700
Average Annual Fixed Costs $6,630
@ 600 Hours / Year, Fixed Costs = $11.05/Hour

Fig. 1—Know How To Estimate Costs To Be A Better Manager

INTRODUCTION

One of the most important costs influencing profit in farming operations is the cost of owning and operating machinery. Machinery costs are one of the few costs that good management can minimize and learning how to accurately estimate machinery costs will aid in cutting costs (Fig. 1).

Accurate cost estimates play an important role in every machinery management decision — when to trade, which size to buy and how much to buy.

There are two main types of machinery costs:

1. **Fixed Costs**—those depending more on how long a machine is owned rather than how much it is used (Fig. 2).

2. **Operating Costs**—those varying in proportion to the amount of machine use.

Fixed costs discussed in this chapter include:

- **Depreciation**
- **Taxes**
- **Shelter**
- **Insurance**
- **Interest**

Operating costs, discussed in later chapters, include:

- **Fuel**
- **Lubrication**
- **Maintenance**
- **Repairs**
- **Labor**

The distinction between *fixed costs* and *operating costs* is clear for all items listed except depreciation and repairs. While depreciation is more a fixed cost than an operating cost, it is somewhat affected by the amount a machine is used, particularly if the annual use is unusually high or low.

On the other hand, repairs usually vary according to amount of use, but the need for some repairs seems to result from deterioration due to the age of a machine as well as how much it is used.

Let's discuss fixed costs and their effect on machinery management.

DEPRECIATION

As a cost, depreciation means a loss in the value of a machine due to time and use. Often, it is the largest of all costs.

Machines depreciate, or have a loss of value, for several reasons, including:

TYPICAL FARMING OPERATION COSTS

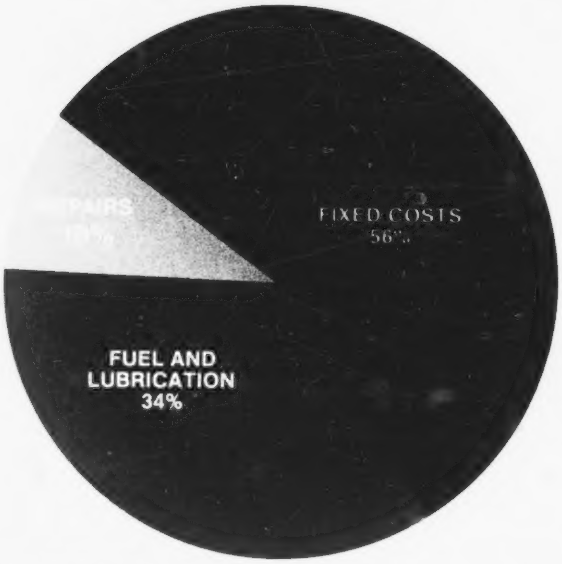


Fig. 2—Fixed Costs Are The Largest Machinery Cost Items

Fig. 3—New Machines May Make Current Machines Obsolete

1. **Age**—Even though model changes may have resulted in little difference in the function of a machine, the newer machine is worth more than an old one.

2. **Wear**—The more a machine is used, the greater the wear. As a result, the ability to function like new may be reduced or it may keep breaking down, meaning it has lost its reliability.

3. **Obsolescence**—If there has been a major model change or a machine no longer has enough capacity, its value may be greatly reduced—even though it may not be worn out. New machine concepts may also be introduced which may obsolete existing similar machines.

There are several different ways to calculate depreciation, including those methods used for figuring income tax. To learn to accurately estimate true costs, we will look at the depreciation methods used most frequently for that purpose. They are:

1. Straight-line depreciation

2. Sum-of-the-digits depreciation

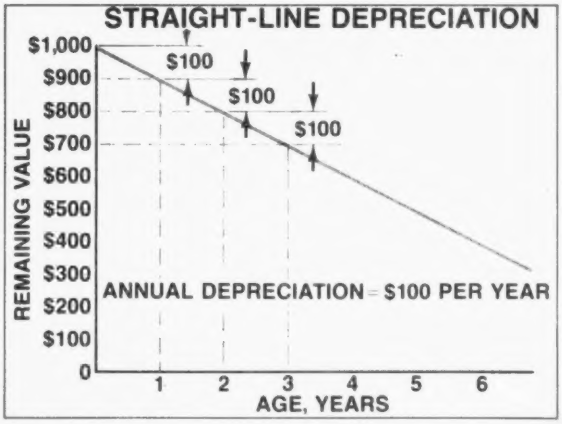
3. Declining-balance depreciation

Let's discuss these different methods of depreciation in more detail.

STRAIGHT-LINE DEPRECIATION

With the straight-line depreciation method, an equal reduction of value is used for each year the machine is owned (Fig. 4). This method can always be used to estimate costs over a specific period of time, provided the proper salvage value is used for the age of the machine. Straight-line depreciation can be

Fig. 4—With Straight-Line Depreciation, The Reduction In Value Stays The Same Each Year



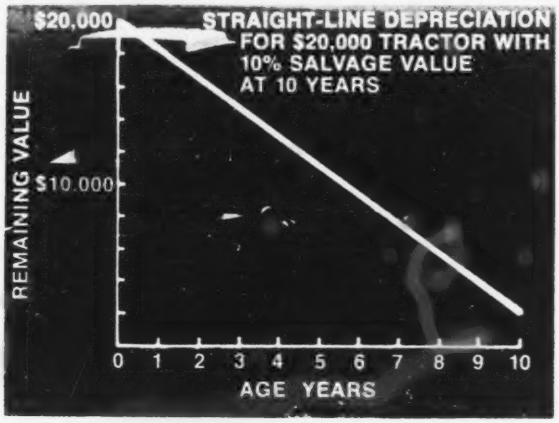


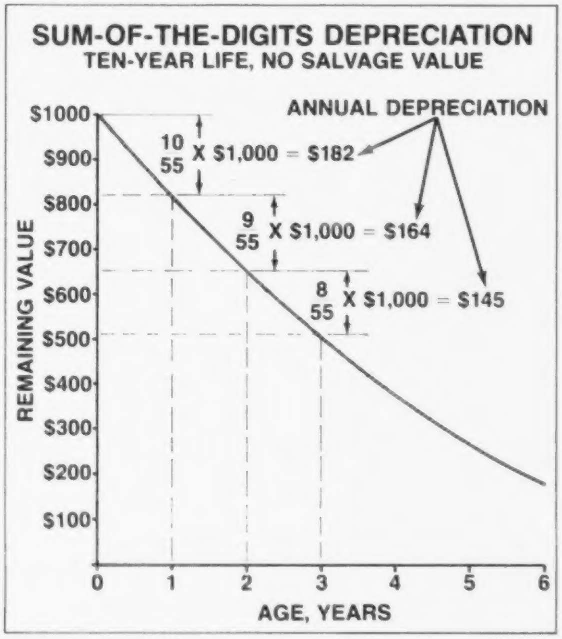
Fig. 5—Straight-Line Depreciation

computed by the following formula for determining **Average Annual Depreciation (AAD):**

$$\text{AAD} = \frac{\text{(Cost)} - \text{(Salvage Value)}}{\text{Years Owned}}$$

The salvage value is a machine's worth at the end of its useful life.

Fig. 6—With The Sum-Of-The-Digits Method, Annual Depreciation Decreases Each Year



Suppose a new tractor is purchased for $20,000 and its "life" is assumed to be ten years. Assume salvage value at ten years (or actual worth) to be ten percent of new cost:

$$\text{AAD} = \frac{(\$20{,}000) - (10\% \text{ of } \$20{,}000)}{10}$$

$$= \frac{\$20{,}000 - \$2{,}000}{10} = \$1800 \text{ per year}$$

As shown in Table 1, $1,800 per year is an effective rate of depreciation for a $20,000 tractor, assuming a ten percent rate per year.

The year-by-year remaining value of the $20,000 tractor over the ten-year life is shown in Table 1.

TABLE 1

STRAIGHT-LINE DEPRECIATION

(For New Machine Worth $20,000)

Year	Depreciation	Remaining Value End of Year
1	$1,800	$18,200
2	$1,800	$16,400
3	$1,800	$14,600
4	$1,800	$12,800
5	$1,800	$11,000
6	$1,800	$ 9,200
7	$1,800	$ 7,400
8	$1,800	$ 5,600
9	$1,800	$ 3,800
10	$1,800	$ 2,000

The straight-line depreciation method is not quite accurate for giving the true value of a machine at some age short of the end of its assumed life. In actual practice, machines depreciate much faster in the first few years than in later years.

The best use for the straight-line depreciation method is for estimating costs over the entire life of the machine (Fig. 5). *As long as the salvage value of a machine is its actual value at the end of its life, average annual depreciation costs can be estimated accurately with this method.*

SUM-OF-THE-DIGITS DEPRECIATION

The sum-of-the-digits depreciation method really means the sum-of-the-years-digits method. It is a much more accurate method of estimating the true value of a machine at any age because the annual depreciation rate decreases as the machine gets older (Fig. 6).

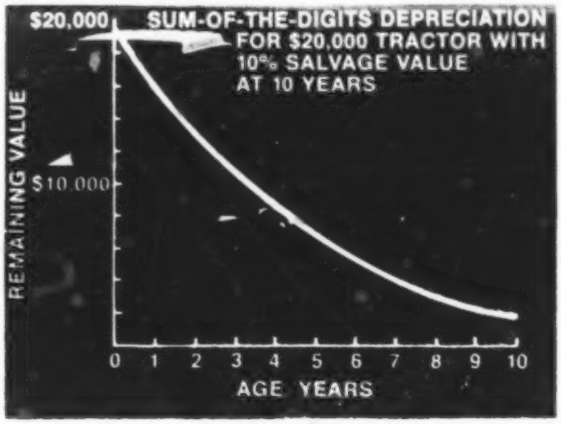


Fig. 7—Sum-Of-The-Digits Depreciation Applied To A $20,000 Tractor

The amount of depreciation by the sum-of-the-digits method is determined in three steps:

1. Add up the numbers representing the years covered by the depreciation period.

2. Divide the total depreciation by the sum of the digits of the years for the depreciation period.

3. Proportion the depreciation in reverse of the years over which the depreciation occurs as shown by the following example.

Applying the sum-of-the-digits method to a $20,000 tractor and assuming a $2,000 salvage value after ten years, we would have the following (Fig. 7):

The total amount to be depreciated is:

(Total value) – (10 percent of total value)

$20,000 – $2,000 = $18,000

As in the example for straight-line depreciation, the tractor would be depreciated over ten years. Following the three steps given:

1. The sum-of-the-digits for ten years is:

10 + 9 + 8 + 7 + 6 + 5 + 4 + 3 + 2 + 1 = 55 units

2. Total depreciation = $18,000 divided by 55:

$$\frac{\$18{,}000}{55\text{ units}} = \$327.273 \text{ per unit}$$

3. Each year's depreciation would be calculated as follows for the first two years:

First year's depreciation = 10 × $327.273
= $3,272.73

Second year's depreciation = 9 × $327.273
= $2,945.45

(Depreciation and remaining value for all ten years is shown in Table 2.)

The sum-of-the-digits method is better than the straight-line method for estimating the true *on-the-farm value* of a machine due to a higher depreciation rate during the early years of machine life.

TABLE 2

SUM-OF-THE-DIGITS DEPRECIATION

(For New Machine Worth $20,000)

Year	Depreciation	Remaining Value
1	10/55 × $18,000 = $3,272.73	$16,727.27
2	9/55 × $18,000 = $2,945.45	$13,781.82
3	8/55 × $18,000 = $2,618.18	$11,163.64
4	7/55 × $18,000 = $2,290.91	$ 8,872.73
5	6/55 × $18,000 = $1,963.64	$ 6,909.09
6	5/55 × $18,000 = $1,636.36	$ 5,272.73
7	4/55 × $18,000 = $1,309.09	$ 3,963.64
8	3/55 × $18,000 = $ 981.82	$ 2,981.82
9	2/55 × $18,000 = $ 654.55	$ 2,327.27
10	1/55 × $18,000 = $ 327.27	$ 2,000.00

DECLINING-BALANCE DEPRECIATION

The declining-balance depreciation method better reflects the actual value of a machine at any age than either the straight-line method or the sum-of-the-digits method.

With the declining-balance method, a machine depreciates a different amount for each year, but the annual percentage of depreciation is the same.

For instance, Figure 8 shows an annual depreciation of 20 percent of the remaining value. By using a first-year correction factor, the declining-balance depreciation method will give a fairly accurate estimate of the remaining value for tractors or equipment.

The value of a machine on the farm is sometimes referred to as the "as is" value. The "as is" value assumes the machine must be sold on the open market without a trade-in or at a farm auction.

The formulas for declining-balance depreciation are listed for the more mathematically inclined. For a more practical and a quicker approach, tables will be used.

First, let's show the principle of a declining-balance formula for a $20,000 tractor—assuming a life of ten years (Fig. 9).

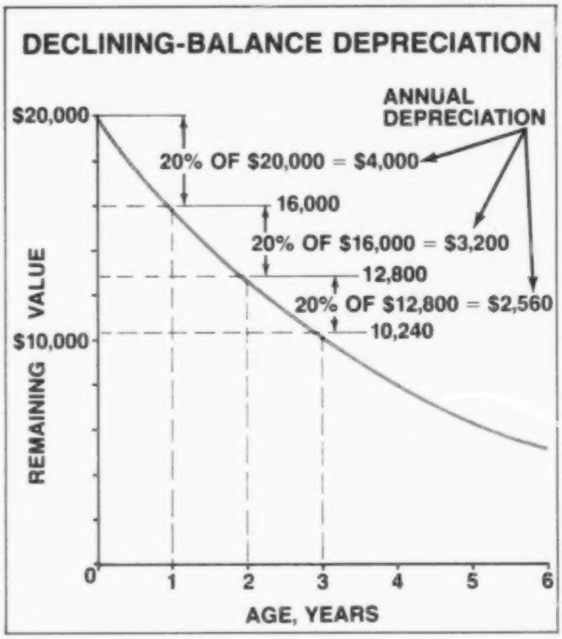


Fig. 8—The Declining-Balance Method Is Best For Estimating On-The-Farm Remaining Values

The formula is:

$R.V. = C \times (1 - \frac{r}{L})^y$, where:

R.V. = remaining value

C = cost

r = rate of depreciation compared to the straight-line method. (If r = 2, the schedule is referred to as a double-declining-balance method. Remembering the ten percent rate in the example for the straight-line method, the double-declining-balance rate would be 20 percent.)

L = life, years

y = age at which depreciation is determined

Assumptions:

C = $20,000

r = 2.0

L = 10 years

At y = 1.0, the end of the first year of ownership, the remaining value (R.V.) is:

$$R.V. = \$20{,}000 \times (1 - \frac{2}{10})^1$$

$$= \$20{,}000 \times (1 - 0.2)^1$$

$$= \$20{,}000 \times 0.8 = \$16{,}000$$

If y = 2, or when the machine is two years old, the remaining value (R.V.) is:

$$R.V. = \$20{,}000 \times (1 - \frac{2}{10})^2$$

$$= \$20{,}000 \times (0.8 \times 0.8) = \$12{,}800$$

Simply, the declining-balance method works on the basis that whatever value a machine has at the beginning of the year, it will be worth a fixed percentage of that value one year later.

In the case of the new $20,000 tractor, its value one year later is 80 percent of costs. Based on this percentage, a ten-year depreciation schedule is shown in Table 3.

TABLE 3

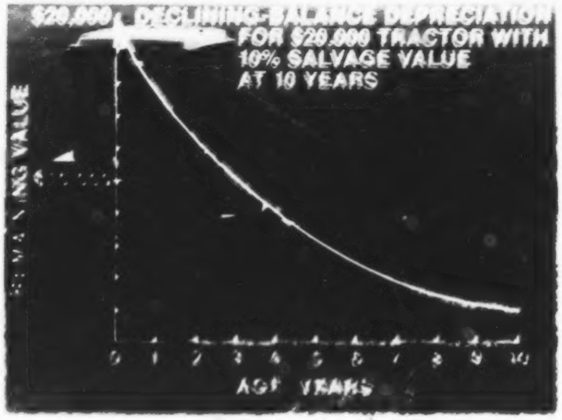
DECLINING-BALANCE DEPRECIATION

(For New Machine Worth $20,000)

Age, Years	Depreciation	Remaining Value
1	$4,000	$16,000
2	$3,200	$12,800
3	$2,560	$10,240
4	$2,048	$ 8,192
5	$1,638	$ 6,554
6	$1,311	$ 5,243
7	$1,049	$ 4,194
8	$ 839	$ 3,355
9	$ 671	$ 2,684
10	$ 537	$ 2,147

With this method, the value of the machine never reaches zero.

Fig. 9—Declining-Balance Depreciation Method For A $20,000 Tractor



Dealer Guide To Used Equipment
Tractor Trade-In Guide

Fig. 10—Dealer's Trade-In Guides Provide Reliable Values Of Used Equipment

In the past few years a careful study of the "as is" values of agricultural machinery has indicated that on-the-farm remaining values more nearly fit the declining-balance method than either the straight-line or sum-of-the-digits methods (Fig. 10).

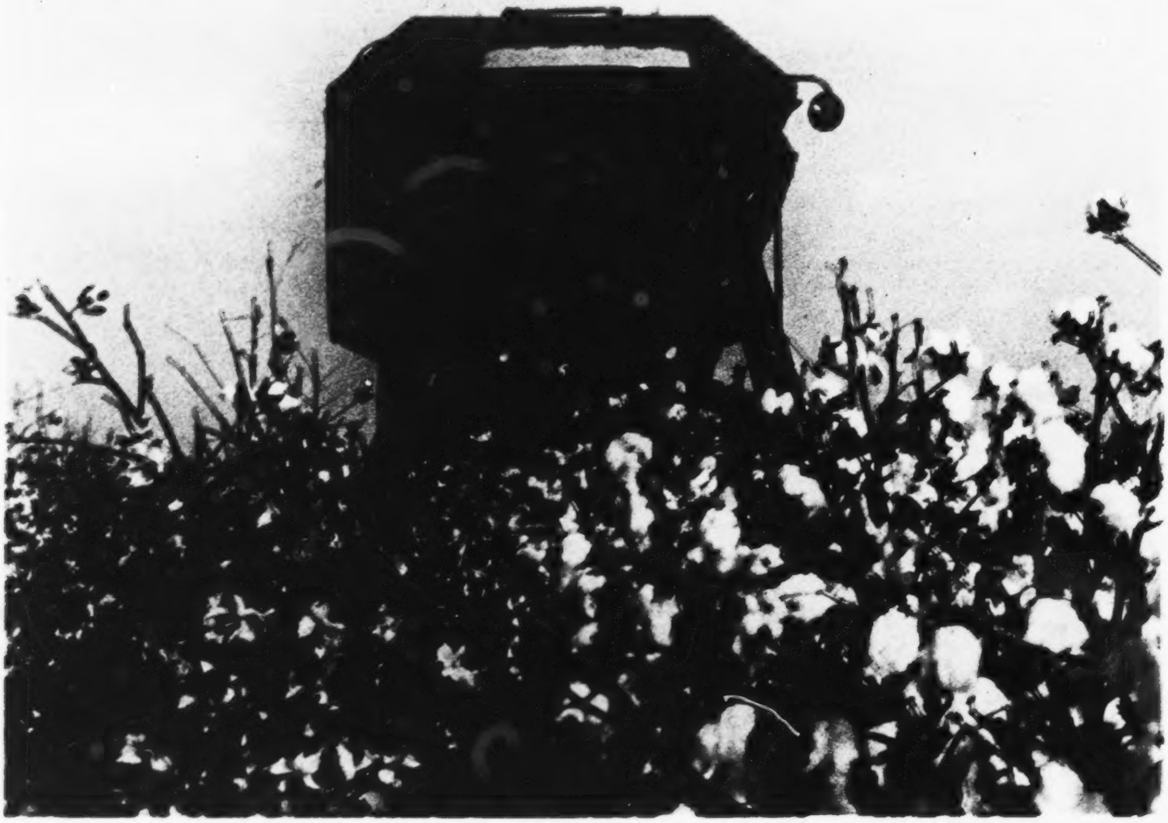
In actual practice, the first-year depreciation is considerably higher, percentage-wise, than the later years (Fig. 11). To provide a more accurate method for estimating the value of machines, a first-year correction factor is added to the declining-balance formula.

For all tractors, including 4-wheel-drive tractors and crawlers, the remaining-value (R.V.) formula is:

R. V. = cost x 0.60 x 0.935 ^{y}

In this formula, the correction factor for the first year depreciation is 0.60. The annual depreciation factor is 0.935. The "y" exponent indicates how many times 0.935, or the annual depreciation factor, is multiplied times itself.

Fig. 11—Farm Machinery Has A High First-Year Depreciation



For example, a $36,000 tractor is worth $17,656 after 3 years:

$$
\begin{aligned}
\text{R. V.} &= \text{cost} \times 0.60 \times 0.935^{3} \\
&= \$36{,}000 \times 0.60 \times 0.935^{3} \\
&= \$17{,}656
\end{aligned}
$$

For all farm machines other than tractors, the formulas are:

Combines $\text{R. V.} = \text{cost} \times .67 \times .92^{y}$

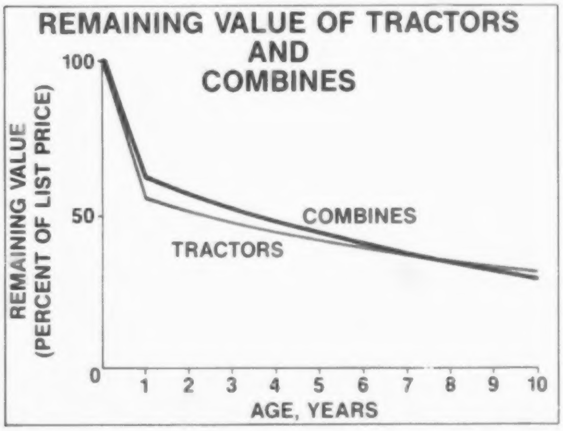
All other Machines $\text{R. V.} = \text{cost} \times .56 \times .90^{y}$

Remaining values are listed in Table 4 as percentages of list prices for all tractor and farm machinery. Figure 12 depicts the remaining values for tractors and machines as percentages of the cost of the tractor or machine when new.

Table 4
Remaining value
Percent of list price

age, years	tractors	combines	all others
0	100.00%	100.00%	100.00%
1	56.10%	61.64%	50.40%
2	52.45%	56.71%	45.36%
3	49.04%	52.17%	40.82%
4	45.86%	48.00%	36.74%
5	42.88%	44.16%	33.07%
6	40.09%	40.63%	29.76%
7	37.48%	37.38%	26.78%
8	35.05%	34.39%	24.11%
9	32.77%	31.63%	21.70%
10	30.64%	29.10%	19.53%

Fig. 12—Chart Showing Average Remaining Values



The percentages in Table 4 are listed to the second decimal to give more accuracy for those desiring to use calculators or computers.

To show how the table works, let's use the following example. Suppose a six-year-old tractor had a list price of $20,000, and an eight-year-old plow had a list price of $2,500. What would be the "as is" values and total depreciation of the tractor and plow, assuming both to be in average condition for their age?

From Table 4, we know the "as is" value of the tractor is 40.09 percent of list price. (To multiply or divide by a percentage, the decimal must be moved two places to the left):

40.09 percent of $20,000 = .4009 x $20,000 = $8,018

Total depreciation for the tractor is:

$20,000 - $8,018 = $11,982

The "as is" value of the plow is: (use "all others" column in Table 4)

24.11 percent of $2,500 = $603

Total depreciation of the plow is $2,500 minus $603 or $1,897.

Total "as is" value of the tractor and plow is:

$8,018 + $603 = $8621 (Fig. 13).

Total depreciation of the tractor and plow is:

$11,982 + $1,897 = $13,879

Remember that tables and formulas used to estimate "as is" values are based on the average of large numbers of reports from across the country. While they provide a good estimate of typical "as is" values, they cannot possibly take into account used equipment values in times of shortage, local situations or variations in models. Therefore, use them only for estimates and not to establish an accurate base for a specific trade.

Information in Table 4 can also be used as a guide to estimate the remaining value of equipment that was purchased used. Once used equipment is purchased, remaining values shown in Table 4 for specific age will still apply.

For example, suppose a four-year-old tractor that sold new for $35,000 is purchased. What will be the remaining value of the tractor after another four years?

When the tractor has been owned another four years, it will be eight years old. Table 4 shows the remaining value to be 35.05 percent of new cost:

Remaining value = 35.05 percent of $35,000 = $12,267

At first glance there would appear to be a discrepancy in the remaining values when a machine or tractor is one year old. These values seem to be very low when they are compared to list price. These figures were updated in 1986 and reflect incentive sales programs by machinery dealers and companies. Table 4 and Fig. 12 are based on list price. Unless otherwise stated, all future cost figures that include depreciation for tractors and machinery will reflect these incentive sales.

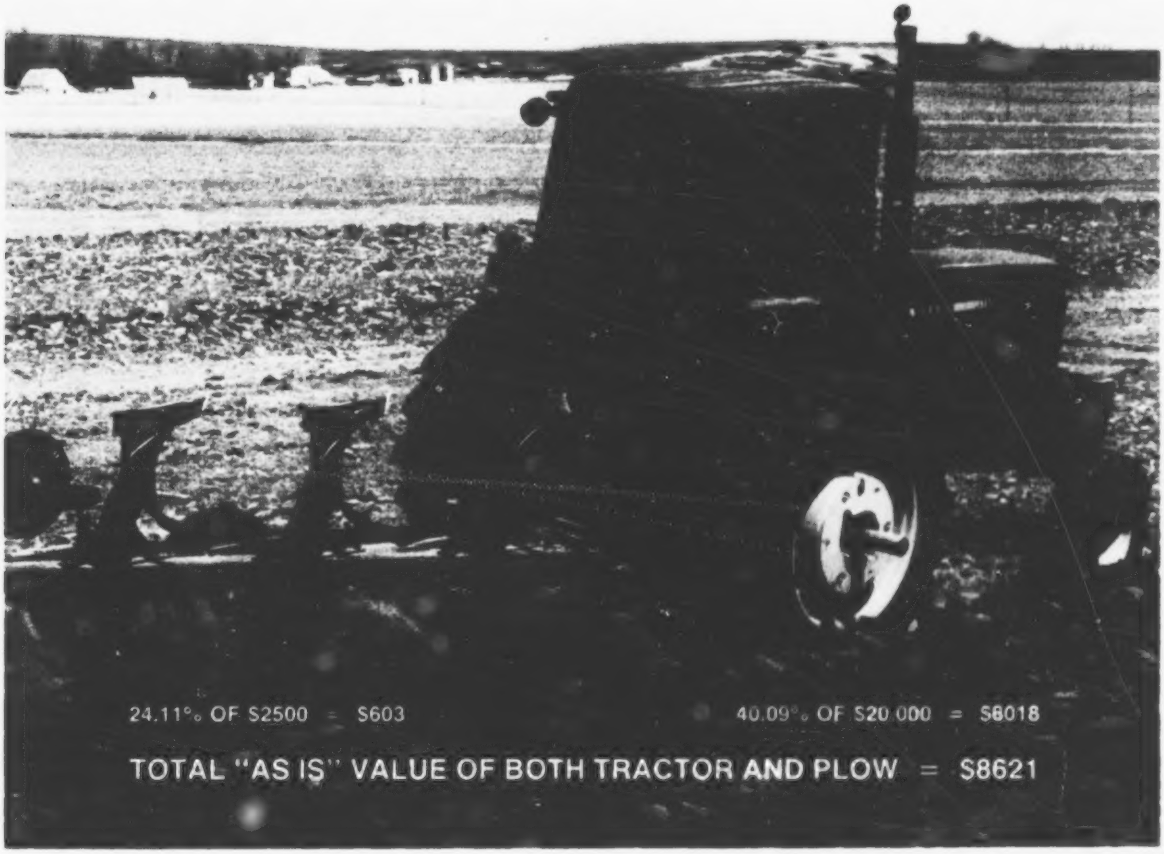

24.11% OF $2500 = $603
40.09% OF $20,000 = $8018
TOTAL "AS IS" VALUE OF BOTH TRACTOR AND PLOW = $8621

Fig. 13—Estimating Remaining Values From Table 4

OTHER FIXED COSTS

Now that depreciation has been discussed, let's take a look at four other fixed costs:

- **Taxes**
- **Shelter**
- **Insurance**
- **Interest**

The abbreviation for these four costs is **TSII.**

TAXES

Taxes are paid on machinery in the same manner as for other property. In some cases, a sales tax is also assessed. The annual charge for taxes would be from one to two percent of the value of the machine at the beginning of the year.

SHELTER

There is a tremendous variation in farmers' use of shelter for agricultural machinery storage. In the dry southwest, shelter is rarely provided. In colder, more humid areas, nearly all equipment may be stored in some kind of a shelter.

Experts agree that if machinery is not stored, more repairs will be needed, machines will deteriorate faster and, in general, higher ownership costs will result.

For this reason, a charge is made for shelter—whether it is actually provided or not (Fig. 14). Typical annual costs for providing shelter, including a service or repair shop, will average one to two percent of the remaining value of the machine.

INSURANCE

Insurance policies are usually carried on more expensive machines while the risk is usually assumed on the simpler, less expensive machines (Fig. 15). The annual charge for insurance or risk is assumed

Fig. 14—Shelter For Machinery Is A Fixed Cost

to be from 0.25 to 0.50 percent of the remaining value of the machine.

INTEREST

A large expense item for agricultural machinery is interest (Fig. 16). It is a direct expense item on borrowed capital. Even if cash is paid for purchased machinery, money is tied up that might be available for use elsewhere in the business. Interest rates vary but usually will be in the range of 8 to 12 percent.

ESTIMATING FIXED COSTS

Taxes, shelter, insurance and interest (TSII) can be combined in order to estimate costs. If the interest rate is set at 10 percent and the others combined at 4 percent, then an annual charge of 14 percent of the remaining value at the beginning of the year would be reasonable for fixed costs. For such a case, the first three years depreciation and TSII (taxes, shelter, insurance, interest) costs for a $35,000 tractor are shown in Table 5.

TABLE 5

EXAMPLE OF TOTAL FIXED COSTS

Year	Remaining Value (beg of yr)	Deprec- iation	TSII Costs	TSII Costs plus Dep
1	$35,000	$15,365	$4,900	$20,265
2	$19,635	$1,276	$2,749	$ 4,025
3	$18,359	$1,194	$2,570	$ 3,764

Notice that TSII costs are 14 percent of $35,000 at the beginning of the first year. By looking at the total fixed costs (depreciation,taxes,shelter,insurance and interest) you can see why frequent trading without high annual use results in high per-acre machinery costs.

Notice that TSII costs are 14 percent of $35,000 at the beginning of the first year. By looking at the total fixed

costs (depreciation, taxes, shelter, insurance and interest) you can see why frequent trading without high annual use results in high per-acre machinery costs.

For purposes of estimates, Table 6 combines all fixed costs. An interest rate of 10 percent is used in Table 6.

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TABLE 6

AVERAGE ANNUAL DEPRECIATION AND FIXED COSTS AS A PERCENTAGE OF ORIGINAL LIST PRICE

Age, years	Tractors	Combines	All Others
1	46.50	40.96	52.20
2	29.00	27.26	32.15
3	22.92	22.33	25.06
4	19.70	19.62	21.25
5	17.64	17.81	18.76
6	16.17	16.46	16.96
7	15.03	15.38	15.55
8	14.11	14.49	14.41
9	13.34	13.72	13.45
10	12.68	13.04	12.63

Suppose a six-year-old tractor with an annual use of 600 hours originally cost $36,000. What is the average cost per year for depreciation, taxes, shelter, insurance and interest as well as the average cost per hour?

After six years, the average annual fixed cost for the tractor is 16.17 percent of list price or:

.1617 x $36,000 = $5,821 per year

At 600 hours per year, the cost per hour would be:

$5,821 divided by 600, or $9.70 per hour

LOW-ANNUAL-USE FIXED COSTS

When a machine has low annual use, the fixed costs per hour of use can reduce profit. Take another look at the problem in the last example. Fixed costs were $9.70 per hour. What happens if the tractor is used only 400 hours per year?

First of all, on an annual basis fixed costs stay the same or in this case, $5,821 per year:

$5,821 divided by 400 = $14.55

Fixed cost per hour changes according to the amount of annual use (Fig. 17). It is important to understand the total annual cost is not greatly affected by amount of use. Therefore, the more time equipment is used, the lower the average fixed cost per unit of work.

Fig. 15—Insurance Is Protection Against Loss And Is Part Of The Cost Of Owning Machinery

Fig. 16—Interest Is A Major Fixed-Cost Expense

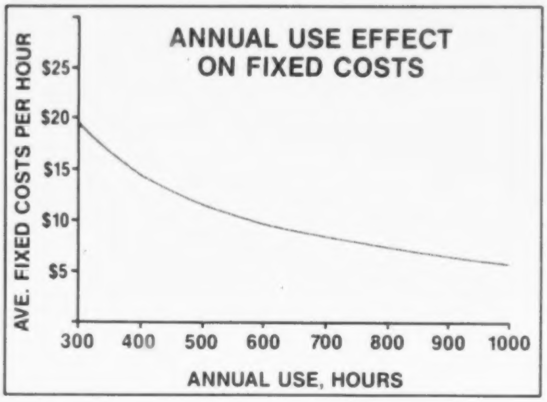


Fig. 17—Average Fixed Cost Per Hour For A $36,000 Tractor

To further illustrate how this important principle could affect profit, let's calculate fixed costs for a self-propelled combine.

Suppose the purchase of a self-propelled combine is being considered and there are two possibilities. One combine costs $56,000, the other costs $44,000. There are 400 acres (162 hectares) of crops to harvest each year. What is the difference in fixed cost per acre if it is planned to own the combine six years?

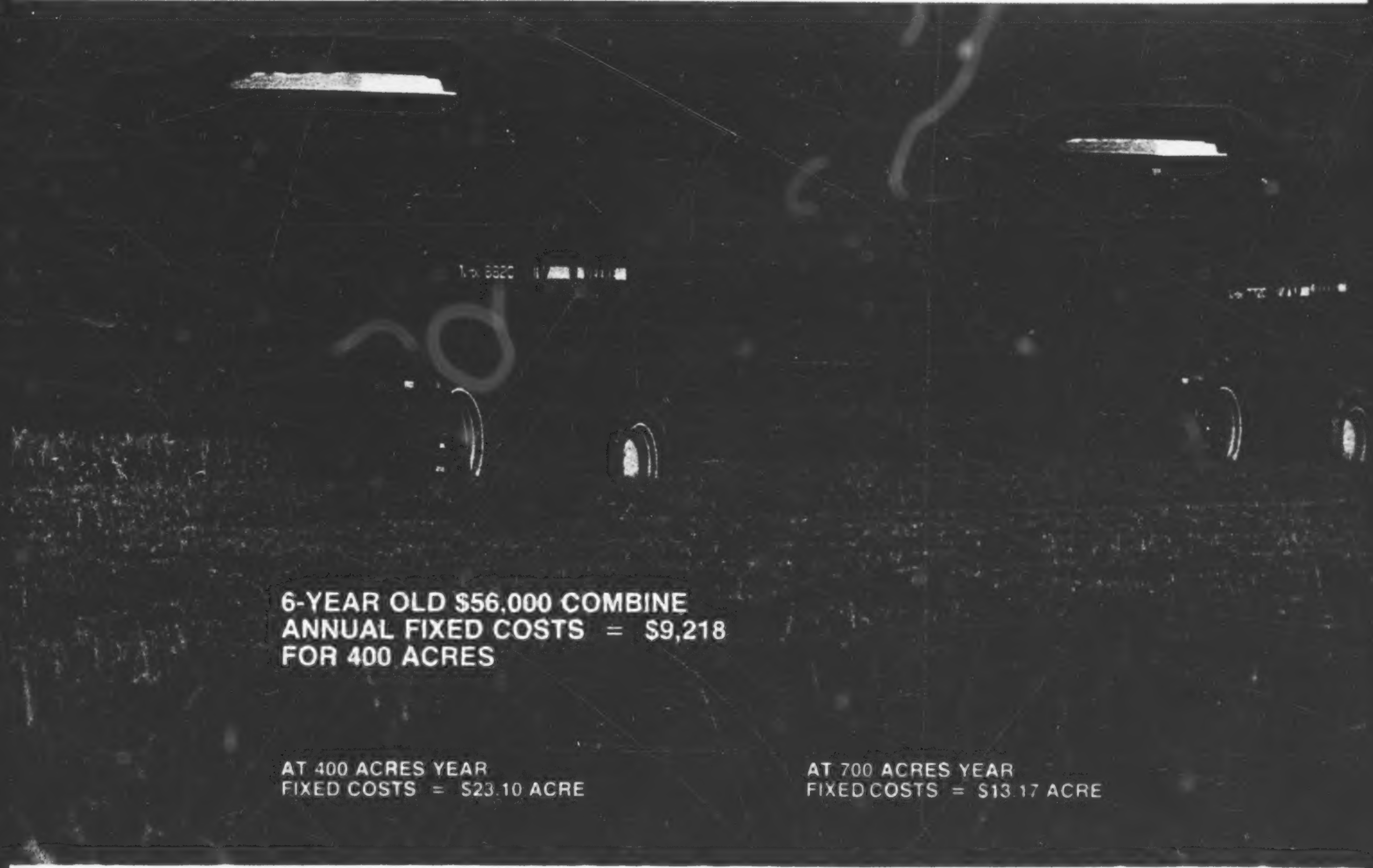
Information in Table 6 shows annual fixed costs average 16.46 percent of cost.

For 400 acres (162 hectares) of use, the $44,000 combine would have fixed costs of:

.1646 x $44,000 = $7,242 per year or $18.10 per acre

Ⓜ .1646 x $44,000 = $7,242 per year or $44.70 per hectare

Fig. 18 — The Greater The Annual Use, The Lower The Fixed Cost Per Acre (Hectare)


6-YEAR OLD $56,000 COMBINE
ANNUAL FIXED COSTS = $9,218
FOR 400 ACRES
AT 400 ACRES YEAR
FIXED COSTS = $23.10 ACRE
AT 700 ACRES YEAR
FIXED COSTS = $13.17 ACRE

For 400 acres (162 hectares) of use, the $56,000 combine would have fixed costs of:

.1646 x$56,000 = $9,218 per year or $23.10 per acre

Ⓜ .1646 x $56,000 = $9,218 per year or $56.90 per hectare

The larger combine would cost $5.00 per acre ($12.20 per hectare) more for a six-year ownership. However, expanding the annual use of the $56,000 combine to 700 acres (284 hectares) would greatly reduce fixed costs per acre (hectare) (Fig. 18):

$9,218 divided by 700 acres = $13.17 per acre

Ⓜ $9,218 divided by 284 hectares = $32.46 per hectare

By expanding the area harvested annually by the $56,000 combine to 700 acres (284 hectares), costs are reduced by $9.93 per acre ($23.10 - $13.17) or by $24.44 per hectare ($56.90 - $32.46).

Of course the $44,000 combine's fixed costs would also decrease. But the question of matching size to the job is critical in this case. The $44,000 combine may not have adequate capacity to get all of the work done within the desired time period available.

HOW TO REDUCE FIXED COSTS

Fixed costs account for 50 to 75 percent of total machinery costs. They are called fixed costs because they vary only slightly with the amount of annual use. Operating costs, including fuel, lubricants and labor, vary directly with usage and stay relatively constant on a per-acre basis. You can reduce fixed costs much easier than you can reduce operating costs. Reducing fixed costs is even more important when you are in a cost-price squeeze or have cash flow problems. Following are some ways you can reduce fixed costs without lowering production.

- Have the proper amount of equipment
- Longer ownership of machinery
- Buy used equipment

HAVE THE PROPER AMOUNT OF EQUIPMENT

If you have the most efficiently matched tractors and equipment, then you will have substantially lower fixed costs than if you have more equipment or larger equipment than you need. For example, suppose that you are efficient with two 125 horsepower tractors that have an initial cost of $40,000 each. You are thinking of buying a 75 horsepower tractor that costs $25,000 to pull some of the lighter draft tools. If you plan to own the tractors eight years then your average annual fixed costs for eight years is 14.11% of list price. Look at Table 6.

14.11% of the list price of the two 125 h.p. tractors is:

.1411 x 2 x $40,000 = $11,288 per year

Adding the 75 h.p. tractor would have the effect of increasing the fixed costs as follows:

14.11% of $25,000 = $3,528 per year (31% increase)

Certainly the added tractor would make some of the farming operations more convenient, but you must be very careful about having equipment that adds to the cost of production without a proportional increase in production.

It is much less expensive for you to use the larger tractors for light loads, than for you to buy an extra tractor.

LONGER OWNERSHIP OF MACHINERY

Another way to hold down fixed costs of farm machinery is to lengthen ownership. Table 7 illustrates how trading too frequently will greatly increase fixed costs. Equipment listed is a basic set for farming 800 acres or row crops.

TABLE 7

	Average annual fixed costs When Equipment Is Traded	
Machine	Every 3 years	Every 8 years
$40,000 tractor	$ 9,168	$ 5,644
$40,000 tractor	9,168	5,644
$100,000 combine	22,330	14,490
$30,000 tillage tools	7,518	4,323
$10,000 seeding equip.	2,506	1,441
Total	$50,690	$31,542

The 8 year trading interval lowers the annual fixed costs from $50,690 to $31,542 or $19,148 per year. If the farm size is 800 acres, then the added costs for trading every three years is $23.94 per acre. In order to own the equipment longer you must have a good maintenance and repair program. A savings of $19,148 a year can help you provide a very sound repair and maintenance program and help you realize higher returns.

Chapter 10 explains some of the procedures that can be used to determine the best time to trade a tractor and other equipment.

BUY USED EQUIPMENT

Buying used equipment is a good way to lower fixed costs, particularly when you are short on finances. There can be a definite financial advantage to purchasing used equipment, however, great care must be taken to be sure that repairs and down time will not more than offset the savings.

Using depreciation schedules (Table 4) given earlier in this chapter, you can estimate the value of any tractor or piece of equipment of any age.

A better source would be local auction sales. There are several options for purchasing used equipment that include buying (1) from an implement dealer; (2) from an auction sale; (3) or direct from another farmer. If you buy used equipment from a dealer, then you might expect to pay more than the "as is" value. A dealer's price might include a reconditioning charge. Dealers also may include a limited warranty.

The following examples illustrate the potential for reducing fixed costs by purchasing used equipment.

Example: What would you expect to pay for a used $36,000 list price tractor that is 4 years old? How much could you save in fixed costs?

Table 4 shows that a 4 year old tractor would have a remaining value of 45.86% of the list price of $36,000.

45.86% of $36,000 is $16,510, which would represent the lower side of what you might expect to pay.

If you buy this tractor from an implement dealer and pay the "add on charge" for reconditioning, then the cost might include the $16,510 plus 25%.

25% of $16,510 = $4,128

$16,510 + $4,128 = $20,638, the price of the used 4 year old $36,000 tractor.

Now we can compare the fixed costs for the used tractor and the new tractor. Use Table 6 to estimate costs for the new tractor. After 4 years, the new $36,000 tractor would have average annual fixed costs of $7,092 (19.70% of $36,000).

The used tractor would have the following fixed costs for the same 4 years of ownership.

Age, Years	Remaining Value	Depreciation	TSII	Total
4	$20,638			
5	$15,437	$5,201	$2,889	$8,090
6	$14,432	$1,005	$2,161	$3,166
7	$13,493	$939	$2,020	$2,959
8	$12,618	$875	$1,889	$2,764

	Total fixed costs, 4 years			$16,979

The average annual fixed costs for the used tractor would be $16,979 divided by 4 or $4,245 per year. The used tractor would have $2,847 ($7,092 - $4,245) less fixed costs per year than the new tractor. Even if the new tractor is owned for 8 years instead of 4 it would still have higher annual fixed costs.

This example shows the savings in fixed costs that might be obtained by purchasing used equipment. It is especially economical when you buy equipment without engines and power trains such as chisels and disks.

The buyer's disadvantage is that they may not know the condition of the used machinery or equipment. The potential cost for excessive repairs and downtime is unknown. The subject is explained in greater detail in Chapter 10.

SUMMARY

To a large extent, fixed costs in machinery control profit. An adequate amount of agricultural machinery is necessary to complete all of the important jobs on time. But, it is important to keep fixed cost per acre down by keeping machinery busy.

Fixed costs include:

- **Depreciation**
- **Taxes**
- **Shelter**
- **Insurance**
- **Interest**

CHAPTER QUIZ

1. List three ways in which machines depreciate.

2. How is straight-line depreciation different from the sum-of-the-digits and declining-balance methods?

3. Using the straight-line method, what is the annual depreciation for a $65,000 combine over a ten-year life if the salvage value is ten percent of cost?

4. In Problem 3, what is the remaining value of the $65,000 combine after three years?

5. What would be the average "as is" value for a $42,000 tractor when it is five years old?

6. You own a $25,000 swather. Use Table 4 to estimate depreciation during the third year of ownership.

7. What different costs are included in fixed costs?

8. What is the average annual fixed cost for a $42,000 tractor that is five years old?

9. Which would have the lowest fixed cost per acre (hectare) of use? A four-year-old, $45,000 combine that is used on 400 acres (162 hectares) per year, or an eight-year-old $30,000 combine used on 800 acres (324 hectares) per year?

10. List three ways to reduce average fixed costs per unit of work done.

7

Estimating Fuel and Lubricant Costs

JOHN DEERE
Turbo 8820

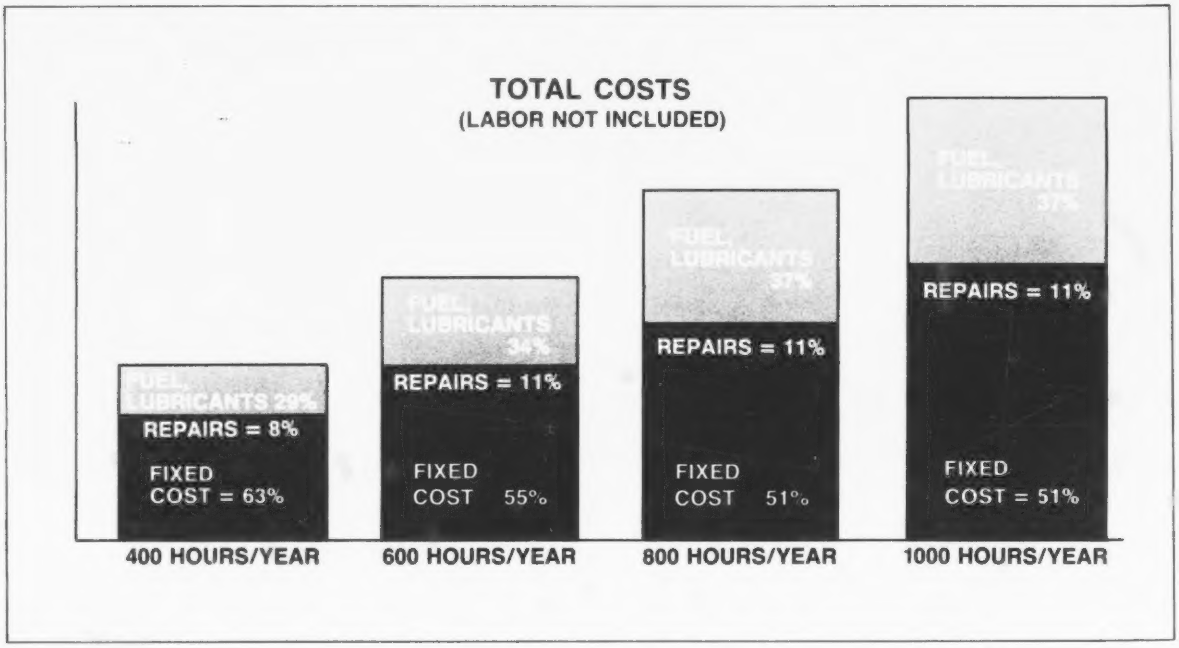


Fig. 1—Fuel And Lubricant Costs Represent About 30 to 40 Percent Of Total Costs For Tractor Operation, Not Including Labor

INTRODUCTION

This chapter covers a factor of increasing importance in machinery management—estimating fuel and lubricant costs. Included are methods for estimating these costs for both tractors and self-propelled machines as well as estimating fuel requirements per acre for various operations.

Fuel and lubricant costs are true *operating costs*. This is because the "per-hour" consumption of fuel and lubricants stays nearly constant from year to year (Fig. 1).

The most accurate methods for estimating these costs are accurate records on similar machines and operations. However, in cases where such records are not available, it is relatively simple to estimate fuel consumption and lubricant costs for specific operations. Estimating these costs is possible because the amount of fuel consumed is directly related to the amount of energy exerted.

Depending on the type of fuel and the amount of time a tractor or machine is used, fuel and lubricant costs will usually represent about 30 to 40 percent of the total machine costs as shown in the example for tractors in Table 1.

Also notice from the information in Table 1 that fuel and lubricant costs become only a slightly higher percentage of total costs as annual use of the tractor increases. Actually, the fuel and lubricant costs per hour stay constant, but the fixed cost per hour decreases as annual use increases. As a result, operating costs (repairs, fuel and lubricants) become a higher percentage of annual costs as annual use increases.

TABLE 1

TRACTOR COSTS

	Annual Use, Hours			
Types of Cost*	400	600	800	1000
Fuel and lubricants	29%	34%	37%	37%
Fixed	63%	55%	51%	51%
Repair	8%	11%	11%	11%

*Labor costs not included

ESTIMATING FUEL NEEDS FOR CROP PRODUCTION

The amount of energy needed per acre for performing operations, such as disking or plowing, is nearly constant, regardless of speed and the size of the tools and tractor being used (Fig. 2).

To better understand how to estimate fuel needs for crop production, we will consider the following factors:

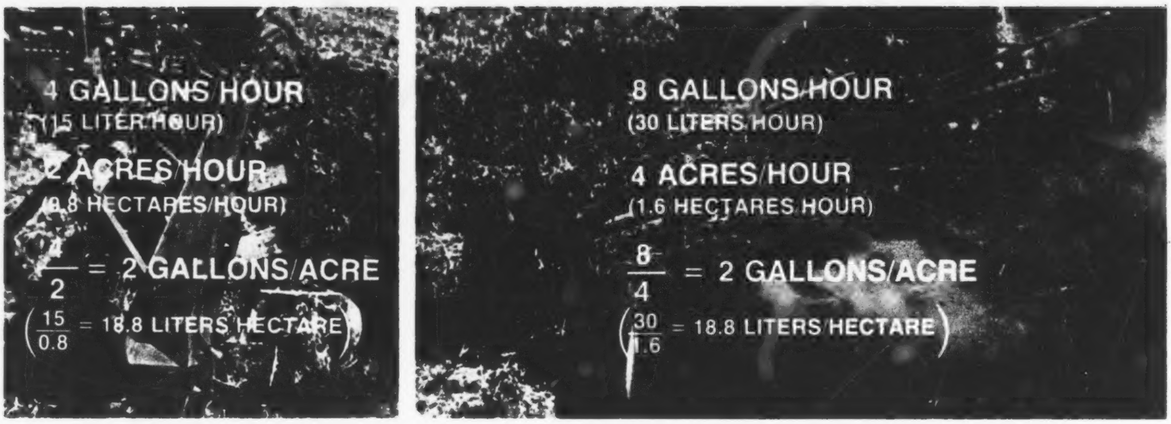


Fig. 2—The Amount Of Fuel Required Per Acre Is The Same For Both Plows

- **Horsepower-hours (kilowatt-hours) capacity**
- **Fuel types**
- **Fuel consumption**

All three factors are important considerations when estimating fuel needs.

HORSEPOWER-HOURS CAPACITY

The amount of fuel needed per acre is in proportion to the amount of energy required. One way of expressing the amount of energy used is "horsepower-hours" (or kilowatt-hours) (Fig. 3). Reviewing the material presented in Chapter 5 on power ratings will aid in understanding this concept.

Horsepower-hours (kilowatt-hours) may be used to measure the work of a tractor in the field. The amounts of energy required for typical farm operations are shown as "horsepower-hours per acre" units in Table 2. Energy requirements in kilowatt-hours per hectare are shown in Table 14 on page 170 in the Appendix.

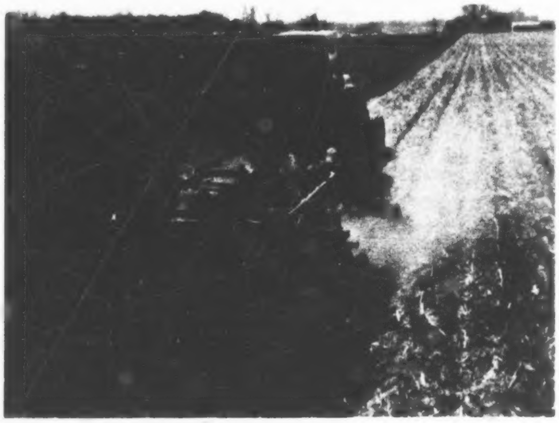


Fig. 3—A 100-HP (75 kW) Tractor Operating At 80 Percent Of Maximum Power For Two Hours Delivers 160 Horsepower-Hours (120 Kilowatt-Hours) Of Energy

As shown in the previous examples, 1 horsepower delivered for 1 hour is 1 horsepower-hour of energy. Likewise, 1 kilowatt delivered for 1 hour is 1 kilowatt-hour of energy. The type of power used in calculating horsepower-hours (and kilowatt-hours) is PTO power.

TYPES OF FUEL

There are three different kinds of fuel used in farm tractors as indicated in Table 2 (Fig. 4). Notice that diesel-engine tractors require fewer gallons per acre than gasoline-engine tractors, while LP-Gas-engine tractors require more gallons per acre of fuel. Table 14 on page 170 in the Appendix also gives fuel requirements for farm tractors in liters per hectare.

For the same amount of work, diesel engines will average about 70 percent as much fuel as gasoline engines. LP-Gas engines require about 20 percent more fuel than gasoline engines. Diesel engines are now standard in most tractors over 100 horsepower (75 kW) due to their fuel efficiency (Fig. 5).

The amount of diesel, gasoline and LP-Gas fuel required per acre for each operation is also shown in Table 2. These fuel consumption estimates are based on averages generally applying to the corn and wheat belt in the central section of the United States.

For year-round operations of main power units, assume an average of 9.0 PTO hp-hours per gallon (1.8 kWh/L) for gasoline, 13.0 PTO hp-hours per gallon (2.6 kWh/L) for diesel and 7.5 PTO hp-hours per gallon (1.5 kWh/L) for LP-Gas (Fig. 4).

Table 2 does not include all field operations, and the figures shown may not fit all situations. However, the information can be used to estimate fuel requirements for a series of similar field operations.

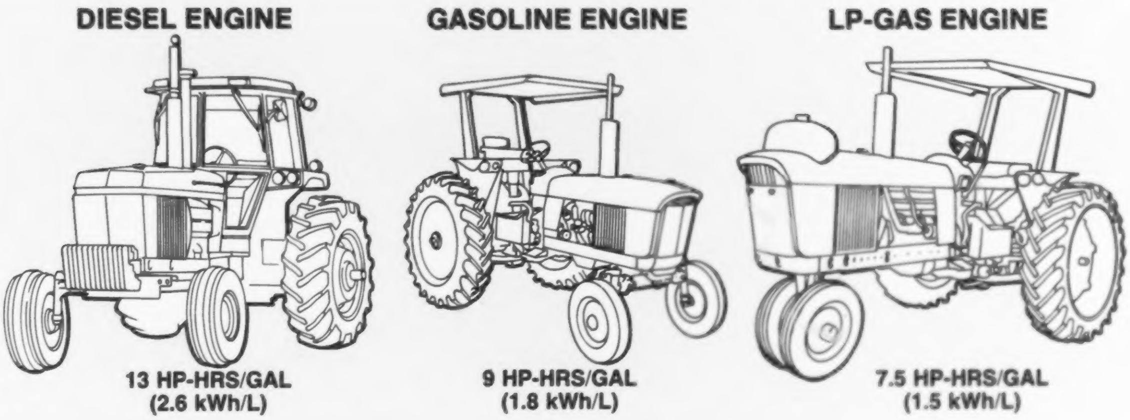


Fig. 4—The Three Fuels Used For Farm Tractors

TABLE 2

AVERAGE ENERGY AND FUEL REQUIREMENTS

Operation	Energy Required, PTO Hp-Hrs. Per Acre	Gallons per Acre		
		Gasoline	Diesel	LP-Gas
Shred stalks	10.5	1.00	0.72	1.20
Plow 8-inches deep	24.4	2.35	1.68	2.82
Heavy offset disk	13.8	1.33	0.95	1.60
Chisel plow	16.0	1.54	1.10	1.85
Tandem disk, stalks	6.0	0.63	0.45	0.76
Tandem disk, chiseled	7.2	0.77	0.55	0.92
Tandem disk, plowed	9.4	0.91	0.65	1.09
Field cultivate	8.0	0.84	0.60	1.01
Spring-tooth harrow	5.2	0.56	0.40	0.67
Spike-tooth harrow	3.4	0.42	0.30	0.50
Rod weeder	4.0	0.42	0.30	0.50
Sweep plow	8.7	0.84	0.60	1.01
Cultivate row crops	6.0	0.63	0.45	0.76
Rolling cultivator	3.9	0.49	0.35	0.59
Rotary hoe	2.8	0.35	0.25	0.42
Anhydrous applicator	9.4	0.91	0.65	1.09
Planting row crops	6.7	0.70	0.50	0.84
No-till planter	3.9	0.49	0.35	0.59
Till plant (with sweep)	4.5	0.56	0.40	0.67
Grain drill	4.7	0.49	0.35	0.59
Combine (small grains)	11.0	1.40	1.00	1.68
Combine, beans	12.0	1.54	1.10	1.85
Combine, corn and grain sorghum	17.6	2.24	1.60	2.69
Corn picker	12.6	1.61	1.15	1.93
Mower (cutterbar)	3.5	0.49	0.35	0.59
Mower conditioner	7.2	0.84	0.60	1.01
Swather	6.6	0.77	0.55	0.92
Rake, single	2.5	0.35	0.25	0.42
Rake, tandem	1.5	0.21	0.15	0.25
Baler	5.0	0.63	0.45	0.76
Stack wagon	6.0	0.70	0.50	0.84
Sprayer	1.0	0.14	0.10	0.17
Rotary mower	9.6	1.12	0.80	1.34
Haul small grains	6.0	0.84	0.60	1.01
Grain drying	84.0	8.40	6.00	10.08
Forage harvester, green forage	12.4	1.33	0.95	1.60
Forage harvester, haylage	16.3	1.75	1.25	2.10
Forage harvester, corn silage	46.7	5.04	3.60	6.05
Forage blower, green forage	4.6	0.49	0.35	0.59
Forage blower, haylage	3.3	0.35	0.25	0.42
Forage blower, corn silage	18.2	1.96	1.40	2.35
Forage blower, high-moisture ear corn	5.9	0.63	0.45	0.76

COMPARING FUEL CONSUMPTION OF CROPPING SYSTEMS

The type of cropping system can also be an important factor in fuel costs. Let's compare two different systems of corn production for the amount of fuel consumed by each system. Assuming the tractor and combine used both have diesel engines, let's compare the two systems as shown in Table 3. Metric conversions for Table 3 appear on page 169 of Appendix. See Table 12 in Appendix.

TABLE 3

COMPARING TILLAGE METHODS

Compare:	SYSTEM 1	SYSTEM 2
Operation	Conventional Tillage gallons per acre	Reduced Tillage gallons per acre
Disk Stalks	0.45	0.45
Plow	1.68 (chisel)	1.10
Disk	0.65	—
Disk	0.65	—
Pre-emergence Spray	0.10	0.10
Field Culti-Mulcher	0.60	0.60
Plant	0.50 (till-plant)	0.40
Cultivate	0.45	0.45
Combine	1.60	1.60
TOTAL	6.68	4.70

In this example, the reduced-tillage method saved 1.98 gallons of fuel per acre (18.5 liters per hectare) (Fig. 6). Of course, reducing tillage operations could also reduce yields or increase yields, depending on the crop, soil, weather and other factors.

ESTIMATING AVERAGE FUEL CONSUMPTION

In order to estimate fuel costs, the average fuel consumption for the machine must be known. While it is possible to estimate fuel requirements for specific levels of draft or loading, it really isn't worthwhile for purposes of estimating costs.

To better understand how to estimate average fuel consumption, we will consider two categories:

1. Average Fuel Consumption For Tractors

2. Average Fuel Consumption For Self-Propelled Machines

Estimating average fuel consumption for tractors is the first essential step for estimating fuel costs.

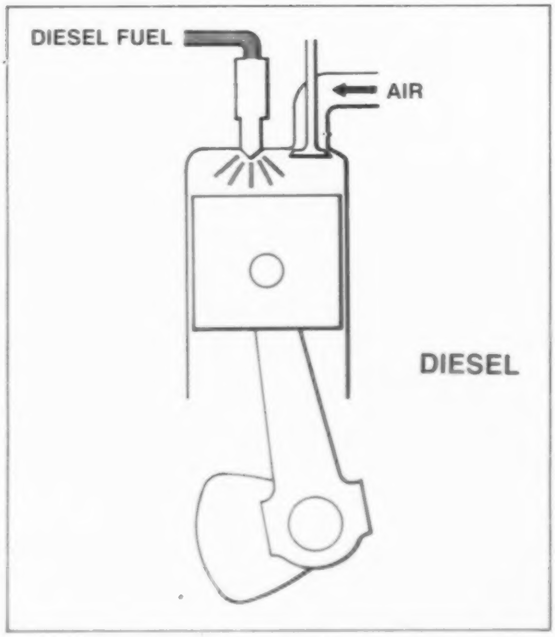


Fig. 5—Diesel Engines Are The Most Efficient Fuel Converters Of The Three Types Of Engines

ESTIMATING AVERAGE FUEL CONSUMPTION FOR TRACTORS

For most farming operations, a tractor will operate at an average of approximately 55 percent of its maximum power during the year (Fig. 7). This figure is based on research work that measured the percent of time the tractor operated at each power level. The results of the research are shown in Table 4.

TABLE 4

PERCENTAGE OF TIME TRACTORS OPERATE AT SELECTED LEVELS OF POWER

Maximum Power, Percentage	Total Time, Percentage
Over 80%	16.8%
60-80%	23.9%
40-60%	22.6%
20-40%	17.5%
Under 20%	19.2%

(Agricultural Engineering Dept., University of Illinois)

JOHN DEERE
1610

Fig. 6—Reduced Tillage Methods Conserve Fuel

Because tractors will usually operate at an average of 55 percent of maximum power on a year-round basis, multipliers have been determined to estimate fuel requirements. These multipliers are listed in the center column in Table 5. Metric conversions for Table 5 appear on page 169 of Appendix. See Table 13 in Appendix. See page 80, METRIC EQUIVALENTS, for the following calculations in metric measurements.

TABLE 5

AVERAGE FUEL CONSUMPTION AND FUEL WEIGHT FOR DIFFERENT TYPES OF TRACTOR ENGINES

Engine (Fuel Type)	Average Fuel Consumption (Gallons Per Hour Per Maximum PTO HP)	Typical Pounds Per Gallon
Gasoline	0.068	6.1
Diesel	0.044	6.9
LP-Gas	0.080	4.25-4.50

If a diesel-engine tractor has 40 maximum PTO horsepower, its fuel use would probably average 1.76 gallons per hour (40 hp x 0.044) on a year-round basis (Fig. 8). A gasoline model of the same size would average 2.7 gallons per hour and a LP-Gas model, 3.2 gallons per hour.

Naturally, some tractors will be more efficient than others and these average figures will not give a perfect answer for every case. However, the variation of any tractor from the average used will make little difference in estimating costs.

To estimate fuel costs once fuel consumption is known, simply multiply the average fuel consumption of the tractor by the fuel cost per gallon.

Suppose the average fuel cost for a 60-horsepower, gasoline-engine tractor is to be calculated with the cost of gasoline at $1.00 per gallon. As shown in Table 5, the fuel consumption multiplier for gasoline is 0.068. The answer is derived as follows:

60 hp × 0.068 = 4.08 gallons per hour, the average fuel consumption (Fig. 9).

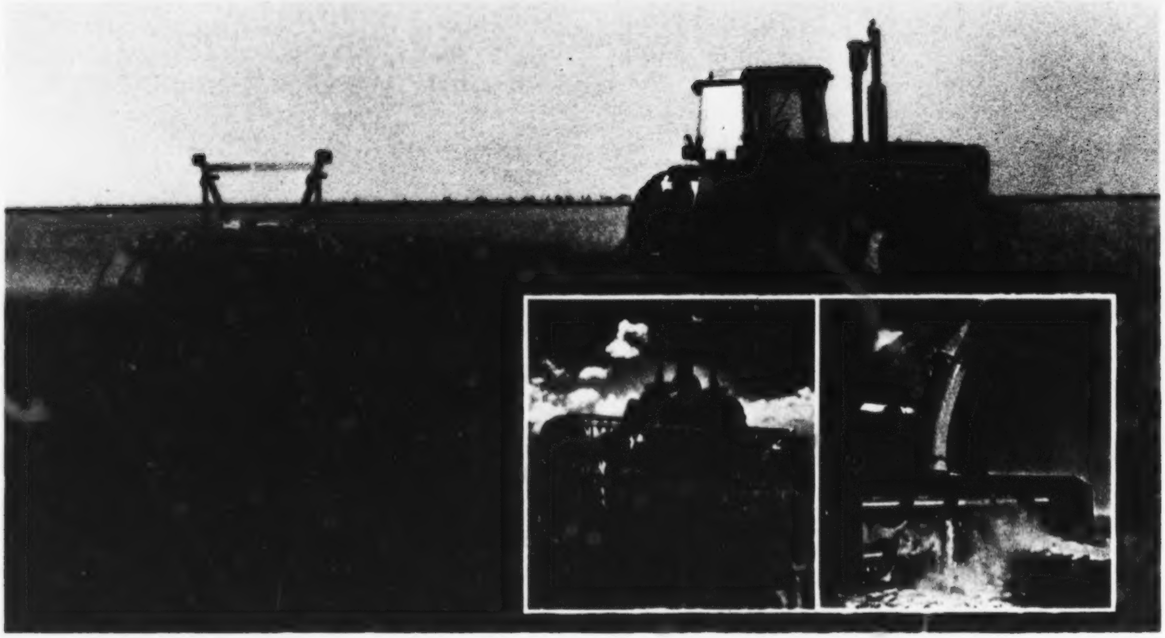
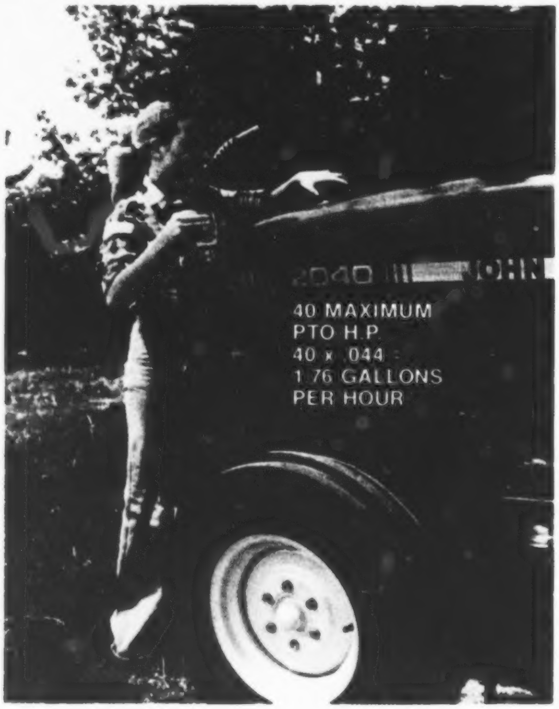


Fig. 7—On A Year-Round Basis, Farm Tractors Will Operate At An Average Of Approximately 55 Percent Of Maximum Power

Fig. 8 — Diesel-Engine Tractors Will Average 0.044 Gallons Per Hour Per Maximum PTO HP on A Year-Round Basis


2040
JOHN
40 MAXIMUM
PTO H.P.
40 x .044 =
1.76 GALLONS
PER HOUR

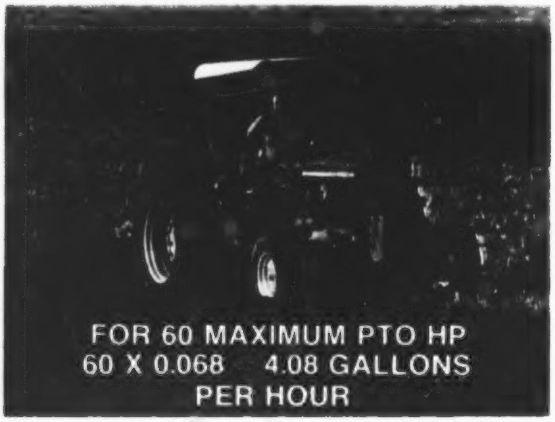
4.08 gallons/hour × $1.00/gallon = $4.08/hour, the average fuel costs.

Estimating fuel costs is discussed in more detail later in this chapter. For metric formulas use Tables 13 and 14 in Appendix. Also see metric equivalents section on page 80.

ESTIMATING FUEL CONSUMPTION FOR SELF-PROPELLED MACHINES

Calculating fuel consumption for self-propelled machines is accomplished the same way as calculating

Fig. 9—Multiply Maximum PTO HP By 0.068 To Get Average Fuel Consumption For Gasoline-Engine Tractors


FOR 60 MAXIMUM PTO HP
60 X 0.068 4.08 GALLONS
PER HOUR

fuel consumption for tractors except we use average fuel consumption per acre, as shown in Table 2. Sometimes fuel consumption is based on the power of the engine of a self-propelled machine. For our purposes, it will be simpler to use Table 2.

One major difference in estimating fuel consumption is that operations involving self-propelled machines, such as combines or self-propelled forage harvesters, usually involve other machines for transport and storage.

Let's use an example of a forage harvesting operation. The total operation consists of chopping the silage, hauling the material to the silo and using a blower to fill the silo.

Considering the distance from the field to the silo in our example, two tractors and wagons will keep the forage harvester and blower operating almost continuously. Going to the information in Table 2 (or Appendix Table 14) the following average fuel consumption figures are given:

- Chopping corn silage (self-propelled harvester, diesel engine) = 3.6 gallons per acre (33.7 L/ha)
- Tractor-powered blower (diesel engine) = 1.4 gallons per acre (13.1 L/ha)
- Transport (two diesel-engine tractors)

0.3 gallons per acre × 2 = 0.6 gallons per acre

Ⓜ 2.8 liters per hectare × 2 = 5.6 liters per hectare

By adding up the amount of fuel involved in each operation, a total of 5.6 gallons per acre (52.4 L/ha) is determined as the total amount of fuel needed per acre for the entire forage harvesting operation.

ESTIMATING AVERAGE FUEL AND LUBRICANT COSTS

The next step after learning to estimate fuel consumption for tractors and self-propelled machines is estimating average fuel and lubricant costs. This important aspect of machinery management will be discussed in two parts:

- **Estimating Lubricant Costs**
- **Estimating Fuel And Lubricant Costs**

Arbitrary figures for fuel costs are used in this book. Always use the actual cost of fuel for each situation as fuel prices vary.

ESTIMATING LUBRICANT COSTS

Modern tractors and self-propelled machines use a wide variety of lubricants—engine oil, grease, transmission oil and hydraulic fluid. The Agriculture Census indicates that lubricant costs were approximately 15 percent of the fuel cost of agricultural machinery (Fig. 10). Once the fuel cost has been estimated, simply by multiplying the cost per unit by consumption, lubricant costs can be estimated as 15 percent of the fuel cost.

Fig. 10—Lubricant Costs Are Approximately 15 Percent Of Fuel Costs

Hydraulic
Gear Lubricant
Wetting Agent

ESTIMATING BOTH FUEL AND LUBRICANT COSTS

Tractor fuel and lubricant costs can be estimated from the alignment chart in Figure 11 by drawing two lines. The alignment chart is relatively simple to use and a fast way to estimate costs.

Let's use an example to show how the alignment chart works. We will use customary U.S.A. measurements only when using the chart. A comparable alignment chart, with metric scales, appears on page 171 of the Appendix, Table 17.

Our example will consist of a diesel-engine tractor with a 150 maximum-PTO-horsepower rating. Diesel fuel in this particular area costs $1.00 per gallon. What would be the average cost per hour of fuel and lubricants for this tractor?

Using the chart in Fig. 12, start at 150 horsepower on Scale A of the nomograph and draw a straight line through the mark for diesel fuel on Scale B until the *turning line* is intersected. In this example it will intersect at 6.6 gallons per hour. The turning line is always the line where the first line drawn is stopped.

For the second step, start a line at the point where the first line crossed the turning line (6.6 gallons per hour) and continue the line through Scale D ($1.00 per gallon) until Scale E is intersected. The line will intersect Scale E at $7.26 per hour — the answer for this particular problem. So the tractor will have an average fuel and lubricant cost of $7.26 per hour if diesel fuel costs are $1.00 per gallon.

Now let's calculate the answer for the same problem by following these steps.

First, calculate the fuel consumption for the tractor by using the information in Table 5:

150 hp x 0.044 = 6.6 gallons per hour (Scale C on the Alignment Chart)

Next, calculate the fuel costs:

6.6 gallons/hour x $1.00/gallon = $6.60/hour

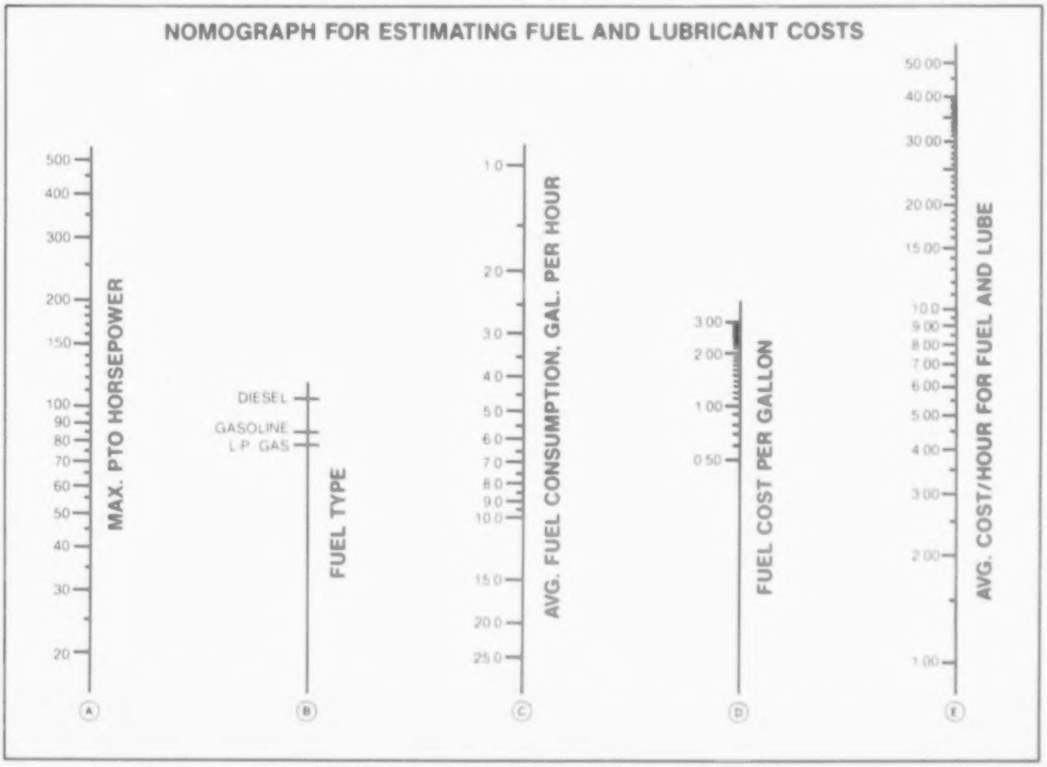
Lubricant costs will average 10 percent of fuel costs:

.10 x $6.60 = $0.66 per hour

Total fuel and lubricant costs are:

$6.60 + $0.66 = $7.26 per hour

Fig. 11—Alignment Chart For Estimating Fuel and Lubricant Costs



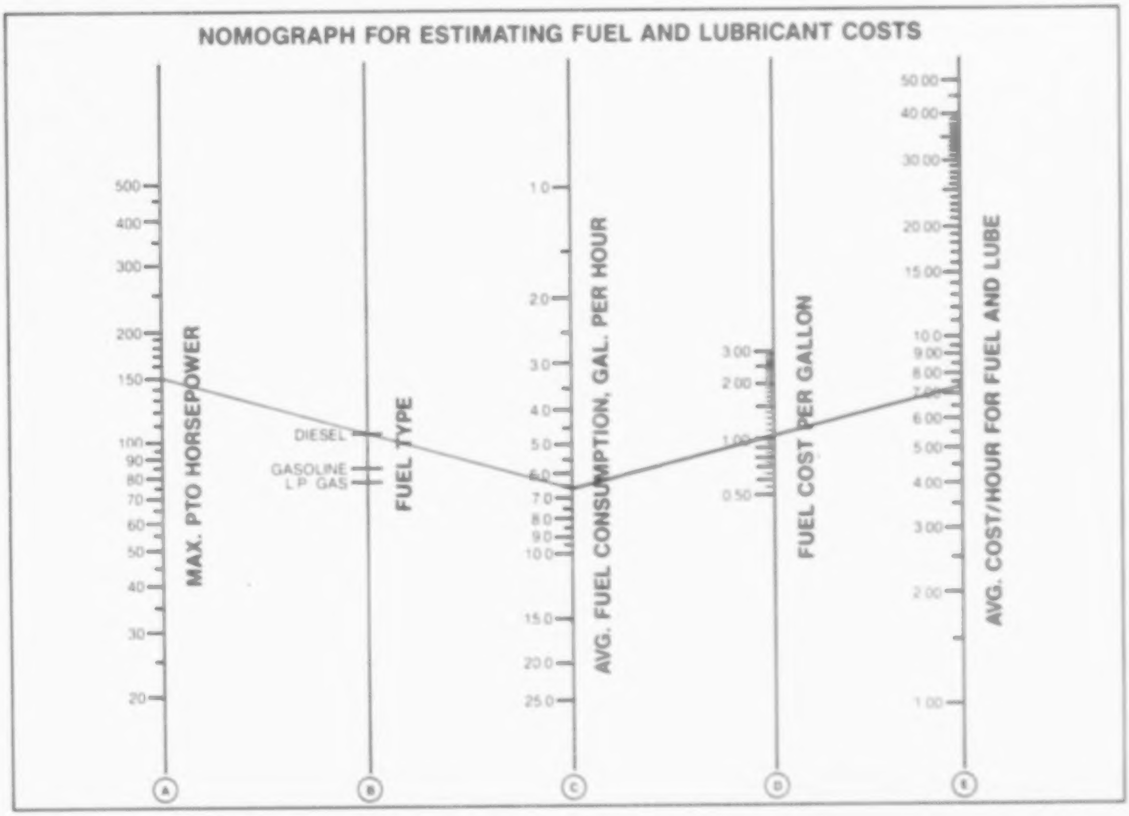


Fig. 12 — A 150 Horsepower, Diesel-Engine Tractor Would Use 6.6 Gallons Per Hour and Have Fuel And Lubricant Costs of $7.26 Per Hour With Diesel Fuel At $1.00 Per Gallon

Fig. 13—Keeping Records Of Fuel Consumption Is The Best Answer For Accurate Fuel Consumption Estimates

When using the alignment chart in Figure 12, remember that only two straight lines are needed and they must intersect on the turning line, Scale C. Again, the answer when estimating fuel and lubricant costs is really an average of a wide variety of sizes and types of tractors.

For the most accurate estimate of fuel and lubricant costs, keep records on each tractor or machine (Fig. 13). But if accurate fuel consumption records are not available, suitable cost estimates can be made by using the methods described in this chapter.

Listed in Table 2 were figures useful for estimating fuel and lubricant costs for machines other than tractors. As with tractors, lubricant costs for self-propelled machines will average approximately 10 percent of fuel costs.

Let's use an example of a 6-row, 30-inch corn combine with a diesel engine. Calculate the fuel and lubricant costs with diesel fuel costing $1.00 per gallon. See pages 80 and 81 for how to calculate fuel and lubricant costs using metric terms.

Information in Table 2 indicates the combine would average 1.6 gallons per acre fuel consumption. First, calculate the fuel cost per acre:

1.6 gallons/acre × $1.00/gallon = $1.60/acre

At 3.5 acres per hour, the resulting fuel cost for the combine in this example would be:

$1.60 per acre × 3.5 acres per hour = $5.60 per hour

Because lubricant costs usually average 10 percent of fuel cost:

$5.60 per hour x 0.10 = $0.56 per hour lubricant cost

The total fuel and lubricant cost in this situation would be $6.16 per hour ($5.60 + $0.56).

FUEL SAVING TIPS

With increasing emphasis on conservation of fuel, try to cut down on fuel consumption whenever possible. Operating costs will also be reduced. Here are some ideas to consider:

1. *Do not make unnecessary tillage trips (Fig. 14).* As shown in Table 2, each tillage trip requires one-half to two-thirds of a gallon of fuel per acre.

2. *Combine operations and operate the tractor at full loads (Fig. 15).* This will save one-half gallon or more per acre because a tractor is more efficient when operating at full load. Two trips with a partial load requires considerably more fuel than one trip fully loaded using combined operations.

3. *Shift to a higher gear and "throttle" back when pulling a light load (Fig. 16).* It takes one-third more fuel when pulling a light load with the governor control wide open than to gear up and "throttle back".

CAUTION—Be careful not to overload the tractor with a reduced engine speed and a higher gear.

Fig. 14—Each Tillage Trip Eliminated Saves One-Half To Two-Thirds Of A Gallon Per Acre

4. *Select tire size and match ballast for proper wheel slippage.* For most operations, 10-15 percent wheel slippage gives the best combination of maximum power at the least fuel usage. Too much slippage can waste as much as 2 gallons per acre.

5. *Keep the tractor in top running condition.* Follow a rigid maintenance schedule and have the dealer give the tractor or machine a periodic service check. A tractor that is operating poorly can waste up to 25 percent of the fuel.

6. *Follow recommended storage practices for fuel tanks (Fig. 17).* Fuel suppliers can provide some good suggestions on storage. Bury gasoline tanks or keep them shaded and use a pressure cap which

Fig. 15—Combining Trips Over The Field Can Save One-Half Gallon Per Acre Or More

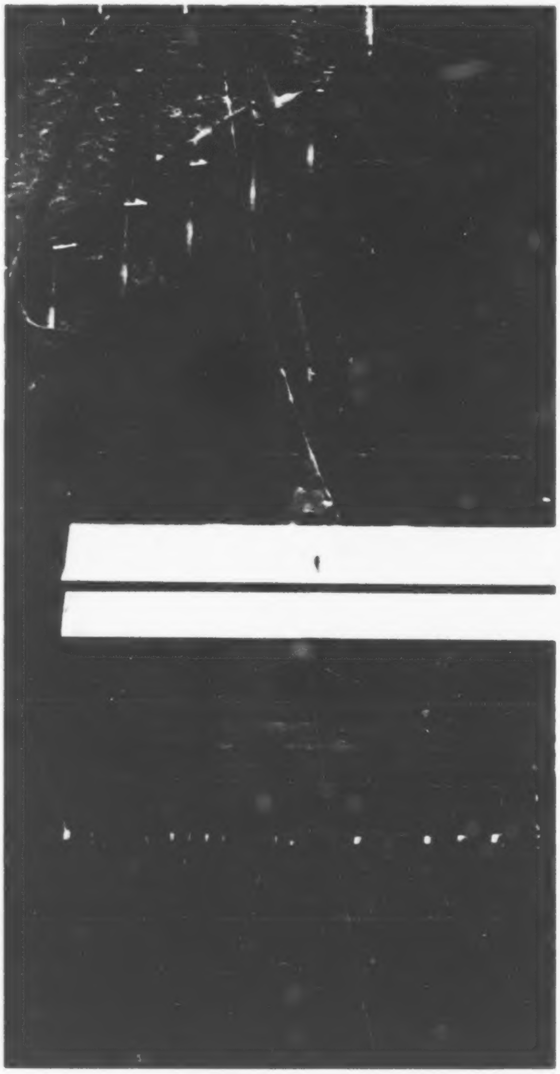


Fig. 16—"Throttle Back" And Shift To A Higher Gear For Light-Draft Implements

conforms to local regulations. Diesel fuel has less tendency to evaporate, but fuel leakage and contamination by dirt and water is still possible. Final filters on fuel tanks are a good investment for helping to protect engines.

METRIC EQUIVALENTS

FUEL CONSUMPTION (METRIC)

Two examples on pages 74 and 75 show how to figure average fuel consumption and fuel cost. Using metric numbers, let's assume a diesel tractor has a 30 maximum PTO kilowatt rating. It's full use would probably average 6.7 liters per hour(30 x .223) on a year round basis. The factor .223 is from Table 13 in Appendix. A gasoline model of the same size would average 10.4 liters per hour and an LP-Gas model, 12.2 liters per hour.

FUEL COST (METRIC)

Now let's suppose the average fuel cost for a 45-kW, gasoline-engine tractor is calculated with the cost of gasoline at $0.26 per liter. As shown in Table 13 in Appendix, the fuel consumption multiplier for gasoline is 0.345. The answer is derived as follows:

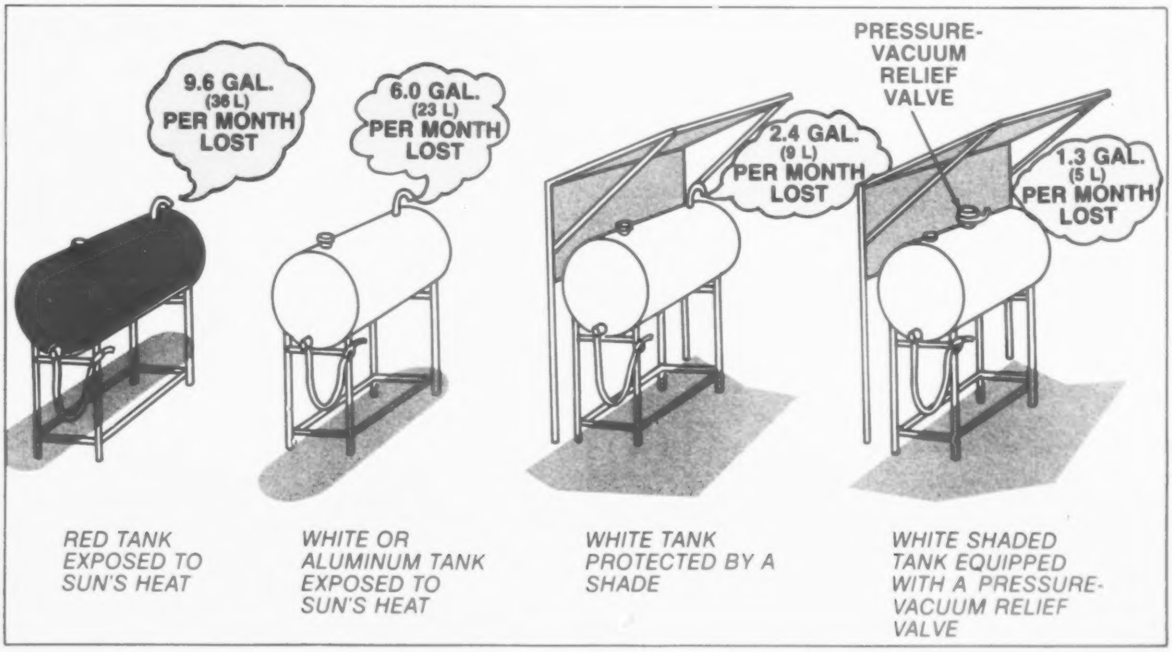
45 kW × 0.345 = 15.5 liters per hour, the average fuel consumption.

15.5 liters/hour × $0.26/liter = $4.03/hour, the average fuel costs.

CALCULATE FUEL AND LUBRICANT COST (METRIC)

For this example, use a 6-row, 75-centimeter corn combine with a diesel engine. Calculate the fuel

Fig. 17—Summer Evaporation Losses From A 300-Gallon (1135 L) Gasoline Storage Tank


9.6 GAL. (36 L) PER MONTH LOST
6.0 GAL. (23 L) PER MONTH LOST
2.4 GAL. (9 L) PER MONTH LOST
PRESSURE-VACUUM RELIEF VALVE
1.3 GAL. (5 L) PER MONTH LOST
RED TANK EXPOSED TO SUN'S HEAT
WHITE OR ALUMINUM TANK EXPOSED TO SUN'S HEAT
WHITE TANK PROTECTED BY A SHADE
WHITE SHADED TANK EQUIPPED WITH A PRESSURE-VACUUM RELIEF VALVE

and lubricant costs with diesel fuel costing $0.26 per liter.

Information in Appendix Table 14 indicates the combine would average 15 liters per hectare fuel consumption. First, calculate the fuel cost per hectare:

15 liters/hectare × $2.26/liter = $3.90/hectare

Because lubricant costs usually average 10 percent of fuel cost:

$5.85 per hour x 0.10 = $.58 per hour lubricant cost

The total fuel and lubricant cost in this situation would be $6.43 per hour ($5.85 + $0.58).

SUMMARY

Fuel and lubricant costs usually represent 20 to 30 percent of machine costs in farming operations. As part of operating costs, fuel and lubricant costs become a larger percentage of annual machinery costs as annual use of the machine increases.

For estimating purposes, the amount of energy needed per acre for each type of operation is nearly constant, regardless of the size of the power unit or machine used. The amount of fuel used is proportional to the amount of energy used in performing each field operation.

Fuel requirements for each type of engine—diesel, gasoline and LP-Gas—vary for the same amount of work because of the different fuel efficiencies of each type of engine.

Estimating the average fuel consumption for a tractor or self-propelled machine is the first step in learning to estimate fuel costs for various operations. Lubricant costs usually can be estimated as 15 percent of fuel cost for both tractors and self-propelled machines.

An important machinery management skill is conserving fuel whenever possible. Fuel prices vary around the country, but can represent important savings in operating costs for the efficient manager.

CHAPTER QUIZ

1. Match each type of fuel with its typical weight per gallon:

a) Gasoline
b) Diesel
c) LP-Gas

1. 6.9 pounds per gallon
2. 4.25-4.50 pounds per gallon
3. 6.1 pounds per gallon

2. (Multiple choice.) On the average, for year-round operation, farm tractors will operate at:

a) 75 percent of maximum power
b) 55 percent of maximum power
c) 45 percent of maximum power

3. How much fuel consumption would a 100 maximum-PTO-hp diesel tractor probably average per hour over a year's time?

4. True or false? "Fuel and lubricant costs are the largest single cost in owning and operating a tractor."

5. (Multiple choice). If fuel costs average $5.50 per hour for your tractor, how much would you expect to spend for lubricants?

a) $1.50 per hour
b) $2.15 per hour
c) $0.55 per hour
d) $8.25 per hour

6. Which type of tractor engine is the most efficient in converting fuel to useful work?

7. How many gallons of diesel fuel would you expect to use to disk stalks, plow, disk, harrow and plant one acre?

8. For average conditions, match the horsepower-hours of energy that can be expected from each type of engine.

a) Gasoline
b) Diesel
c) LP-Gas

1. 7.5 hp-hrs
2. 9.0 hp-hrs
3. 13.0 hp-hrs

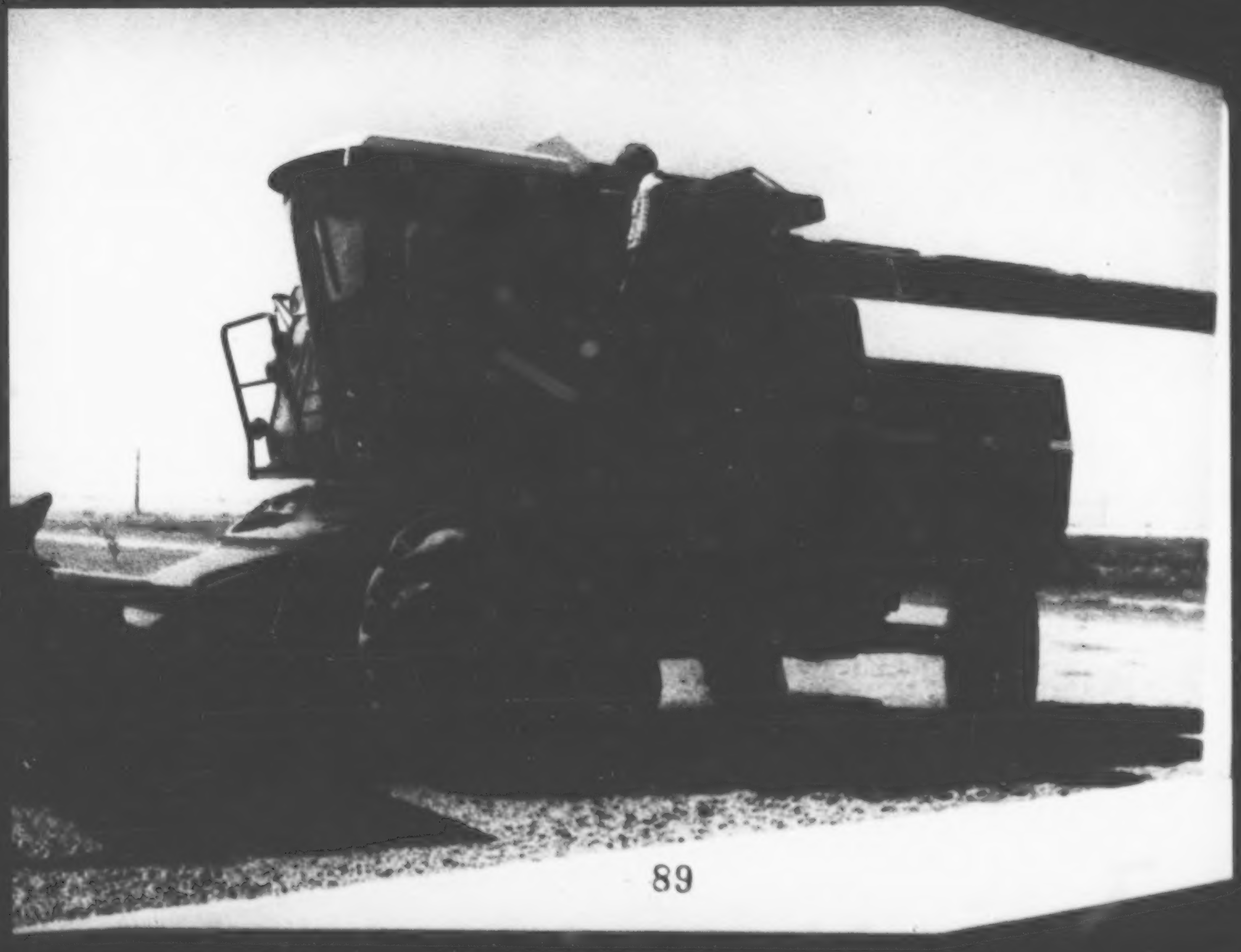
9. Estimate the average fuel and lubricant costs for a 60 hp gasoline tractor with gasoline at $1.25 per gallon.

a) $5.87 per hour
b) $5.10 per hour
c) $0.75 per hour
d) $7.50 per hour

10. List three important ways to save tractor fuel.

8

Estimating Repair Costs



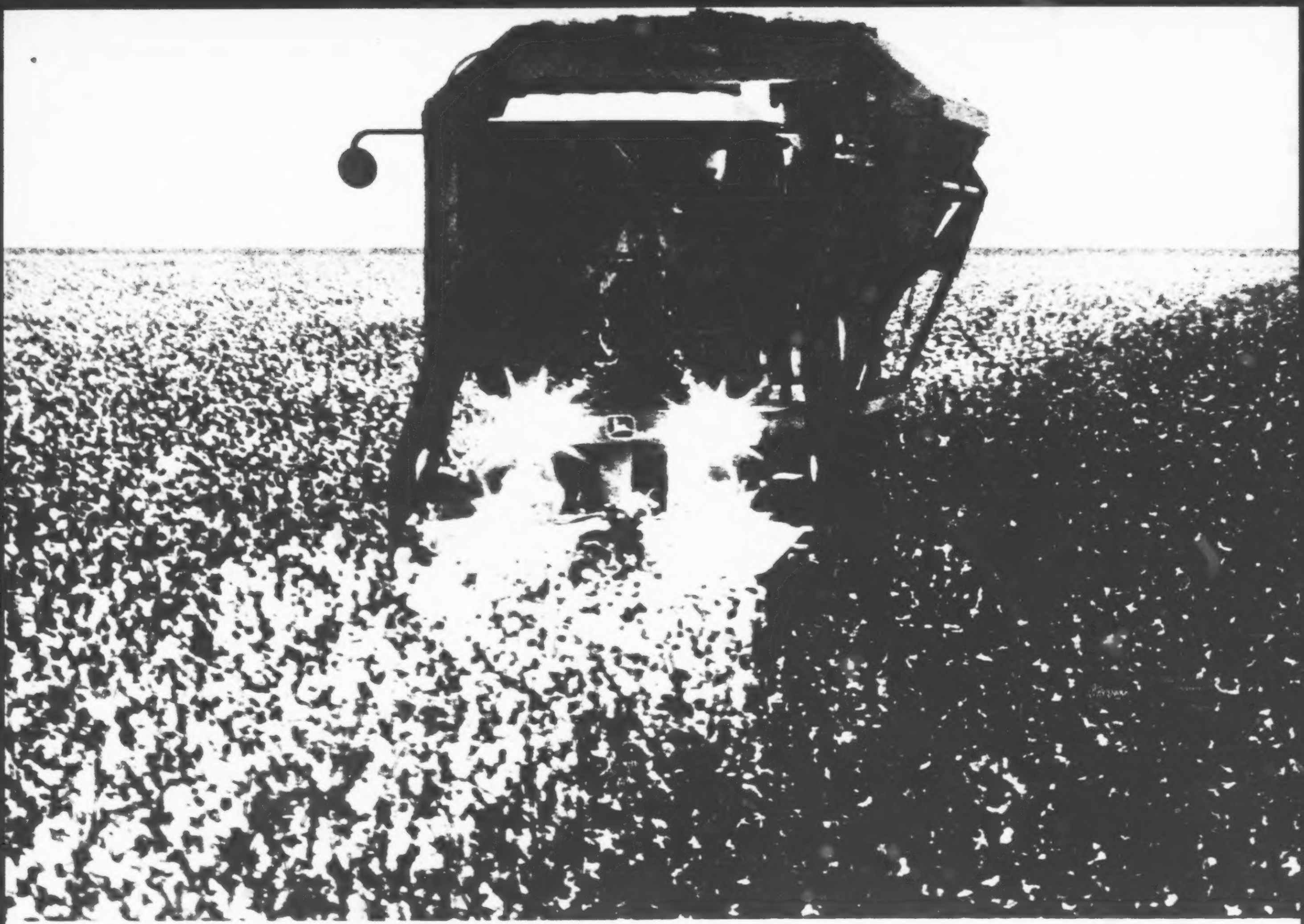
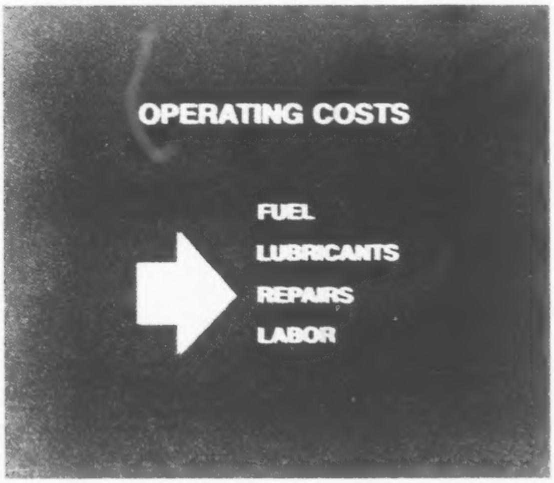


Fig. 1—It Is Important To Keep High-Value Operations Going At Full Capacity

Fig. 2—Consider All Repair Costs As An Operating Cost



OPERATING COSTS

FUEL

LUBRICANTS

REPAIRS

LABOR

INTRODUCTION

Repair costs, usually considered an operating cost, are another important part of machinery costs (Fig. 1). The more a machine is used, the greater is its need for repairs.

However, some machine components have surfaces that rust, rot or otherwise deteriorate over the years. Repair costs caused by deterioration, though not necessarily affected by the amount of use, are still considered an operating cost (Fig. 2).

Have you ever given serious thought as to why repairs are needed? One answer might be, "you have to fix it if you want it to run." In other situations, repairs are necessary for a machine to do its job properly. The purpose for repairing a machine, then, is to maintain its reliability and to keep it performing its task properly (Fig. 3).

The longer agricultural machinery is used, the more repairs are needed to maintain "reliability". Reliability is hard to measure with a formula as it expresses the amount of confidence placed in a machine to perform without an unplanned time loss due to a breakdown.

Repair costs should be considered as a necessary and important part of machinery ownership. Repairs are essential in order to maintain a high level of reliability (Fig. 4).

With the growth in the average size of new tractors and machines, greater productivity is possible. But this *greater productivity* means that it is even more important to avoid breakdowns or to be able to make quick repairs. Even one hour during periods of critical operations in farming is valuable. For example, a breakdown due to a planting delay can mean $75 or more per hour in yield loss (Fig. 5).

Yield-loss cost is probably more important than direct cost of repairs. Make it a goal, once a machine is purchased, to provide necessary maintenance and repairs to keep it running at a high level of reliability.

The aspects of repair costs and reliability considered in this chapter include:

- *Types of repairs*
- *Calculating lost-time costs*
- *Estimating repair costs*
- *Establishing life of equipment*

Let's discuss these factors in more detail.

Fig. 3—Repairs Keep The Machine In Proper Operating Condition

Fig. 4—Improved Reliability Is The Payoff For Keeping Machines In Top Condition

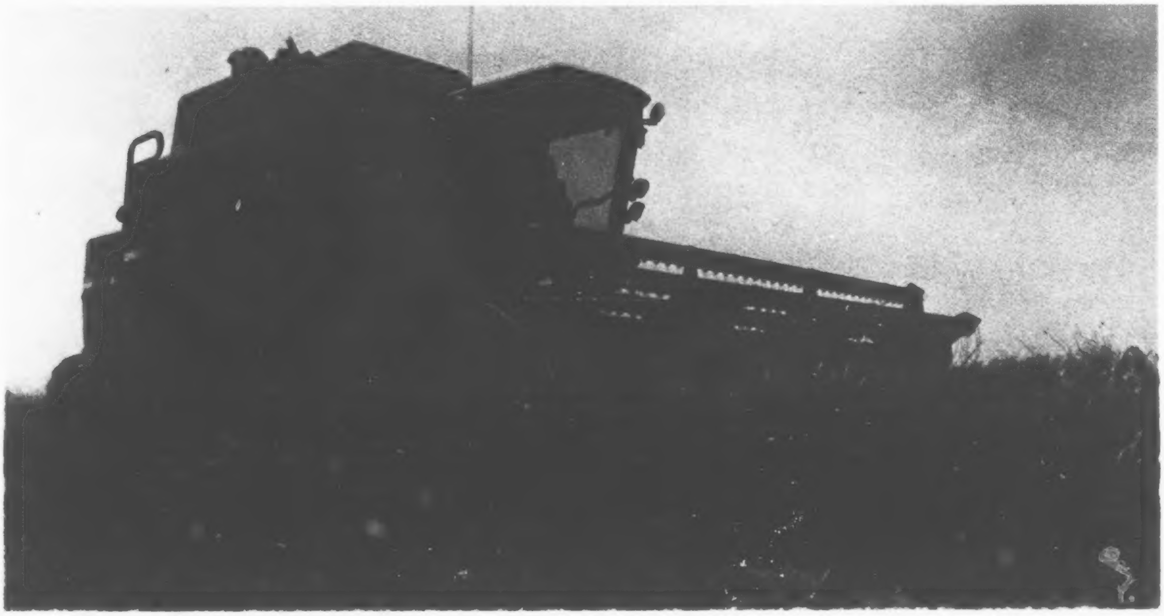


Fig. 5—Each One-Hour Delay In Planting Can Result In A Timeliness Cost Of $75 Or More In Yield Reduction

TYPES OF REPAIRS

With any machine there are four main types of repairs. These types are:

1. **Routine wear**
2. **Accidental breakage or damage**
3. **Repairs due to operator neglect**
4. **Routine overhauls**

Let's discuss each of the four types of repairs and compare what effect management might have on either cost or reliability.

ROUTINE WEAR

Typical examples of routine wear (or replacement) would include plowshares, disk blades, sickles, tires and batteries (Fig. 6). Even with the best of care, replacement will be necessary sooner or later.

But if a rigid maintenance schedule is followed and the equipment or machine is not abused, an increase of 50 to 100 percent in parts life can result, depending on the nature of the part.

Except for excessive abuse, the life of plowshares, disk blades and other soil-engaging parts is usually determined by the soil characteristics. Other parts, like tires and batteries, have a life that is affected by maintenance.

ACCIDENTAL BREAKAGE

Machinery accidents can happen even with the best of operators. But carelessness or rushing a job is far more likely to cause costly accidents (Fig. 7). Unfortunately, these types of accidents often involve a frame, axle, housing or some other part that is hard to replace. Often these types of parts are not stocked by a dealer, or the total damage to the machine is quite extensive.

Fig. 6—Some Repairs Are Due To Routine Or Normal Wear

With good management, few, if any, repairs of this nature are needed. Using good judgment can eliminate most accidental breakage.

OPERATOR NEGLECT

Sometimes, the "time" is not taken to perform needed maintenance or minor repairs. Neglected maintenance and minor repairs almost always lead to more serious problems (Fig. 8).

Remember that putting off maintenance and minor repairs can be costly. Use a good off-season repair program together with a rigid daily inspection and service schedule to help avoid expensive repairs (Fig. 9).

ROUTINE OVERHAULS

Machines are overhauled to replace worn or defective parts and restore original performance. Overloading and poor maintenance practices can accelerate these repairs by 100 percent or more. Records of repair costs compiled by the Agricultural Engineering Department, University of Illinois, show that with good management, repair costs can be reduced by 25 percent or more (Fig. 10). Poor management can raise repair costs 25 percent above the average.

Fig. 7—This ROPS Enclosure Will Have To Be Replaced And The Tractor Repaired Due To An Accident

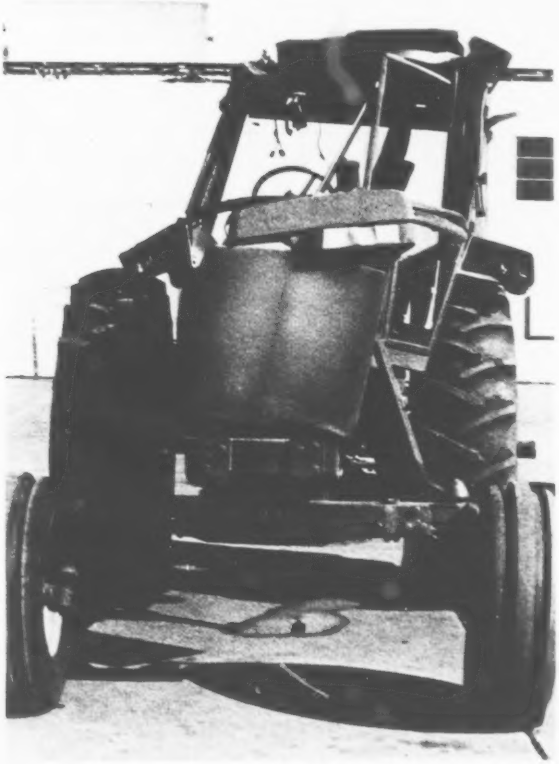


Fig. 8—Neglecting Maintenance Can Lead To Expensive Overhauls

CALCULATING LOST-TIME COST

Applying a little simple arithmetic to machine reliability serves as a strong motivation to improve machine operation.

Suppose a combine can harvest soybeans with a 6-row, 30-inch (75-centimeter) header at 3.25 miles per hour (5.2 kilometers per hour). The theoretical capacity is 5.9 acres (2.4 hectares) per hour or 47.2 acres (19.2 hectares) in 8 hours.

Fig. 9—Periodic Tune-Ups Are Needed To Prolong Engine Life

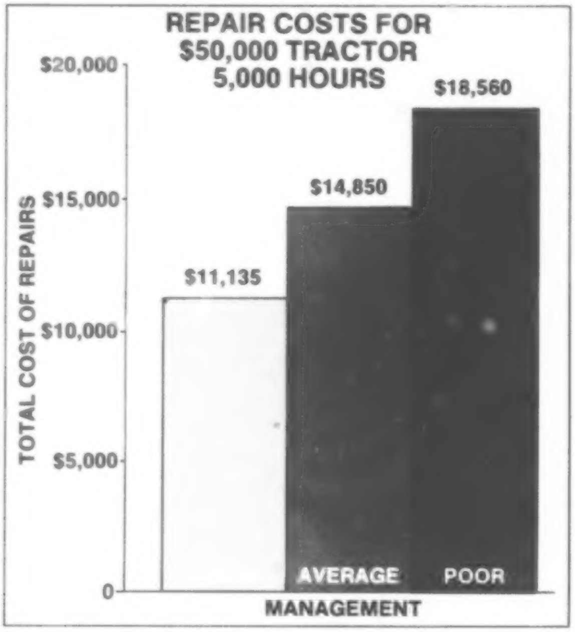


Fig. 10—Good Management Means Lower Repair Costs

Of course, it is impossible to maintain theoretical capacity for a long period of time. Records show that 75 percent field efficiency is possible in this case with proper management and *no breakdowns.* At 75 percent field efficiency, it is possible to combine 4.4 acres (1.8 hectares) per hour and 35.2 acres (14.25 hectares) in 8 hours.

If just one hour a day is lost due to unplanned stops for minor repairs, capacity would be further reduced to 30.8 acres (12.5 hectares) per day. At a custom rate of $20.00 per acre ($50.00 per hectare), the 4.4 acres (1.8 hectares) per day of production would cost an equivalent of about $88.00.

As a rule of thumb, it pays to spend from one to two days in the slack season to avoid a one-hour loss when the machine is needed. With increasing need for larger-capacity equipment, every effort should be made to keep machines in top shape (Fig. 11). An excellent maintenance program to keep machines in top condition is one of the best possible investments.

ESTIMATING REPAIR COSTS

Repair costs consist of *all expenditures* for parts and labor for repairs made in a shop or on the farm. It is difficult to predict repair costs for a specific machine. Repair costs will vary from one geographical section of the country to another because of differ-

Fig. 11—Reliability Is Even More Important With Larger, High-Capacity Machines

ences in soils, crops, climate and operators (Fig. 12).

Even with the expected wide variation, repair costs have been checked and averaged on several different kinds of machines to provide a basis for repair cost estimates.

Repair cost estimates presented in this chapter should be considered only as guidelines in arriving at average cost estimates. *Any time accurate figures are available for each operation, use them instead of the table values in this book.*

ESTABLISHING LIFE OF EQUIPMENT

Usually repair costs are related to how much a machine is used. Therefore, before estimating how much to expect in the way of repair costs, it is necessary to set some limits on the total maximum life a machine can be expected to continue operating. Then we can develop some guidelines for repair cost estimates.

Information in Table 1 indicates the average maximum life to expect from typical farm machinery with average annual usage. It is quite possible to have a tractor or machine in good running condition well beyond the limits shown. To exceed these limits, extra maintenance and repairs would be necessary in most cases.

TABLE 1

ESTIMATED MECHANICAL LIFE

Machine	Predicted Maximum Life, Hours
2- and 4-Wheel Drive Tractors	10,000
Crawlers	16,000
Combines	3,000
Hay Harvesting Equipment	2,000
Cotton Harvesters, Corn Heads	2,000
Tillage Equipment	2,000
Mowers, Planters, Drills	1,000

A number of studies of agricultural machines in Illinois and Indiana was made by the Agricultural Engineering Department, University of Illinois, to determine repair costs for various machines. Results of the study indicated a wide variation in repair costs according to the kind of machine and the way it is used. Complicated formulas for estimating repair costs based on these studies, have been developed.

Because these formulas are not directly usable for cost-estimating purposes, the following table has

Fig. 12—Repair Costs Vary In Different Parts Of The Country

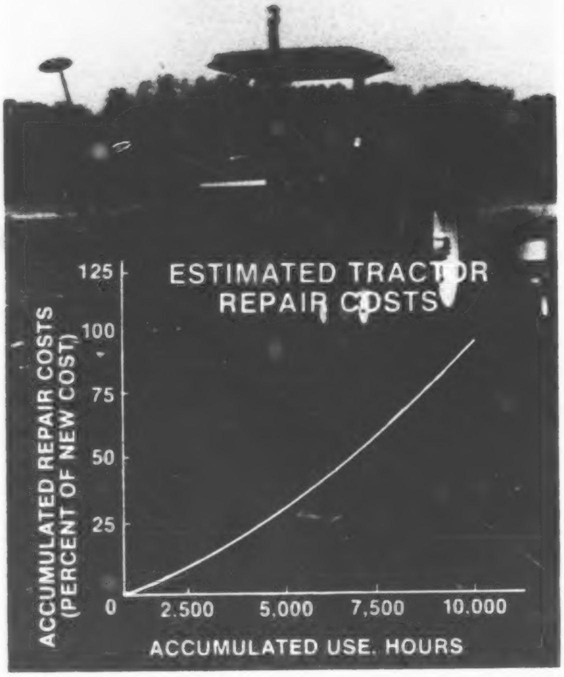
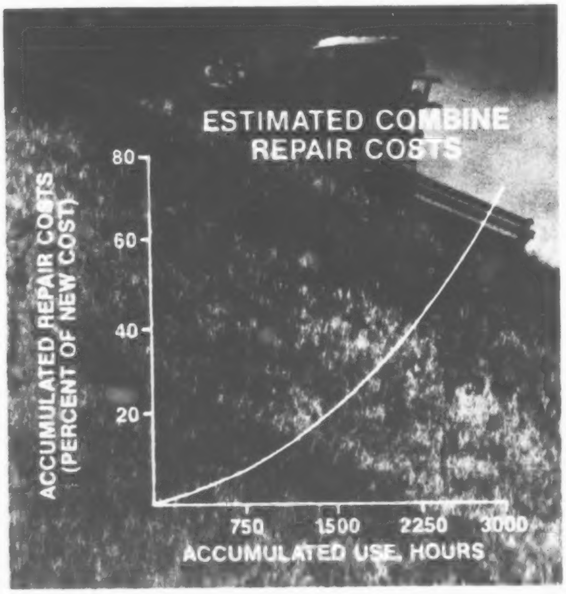


Fig. 13—Estimated Repair Costs For 2- And 4-Wheel-Drive Tractors

Fig. 14—Estimated Repair Costs For Combines



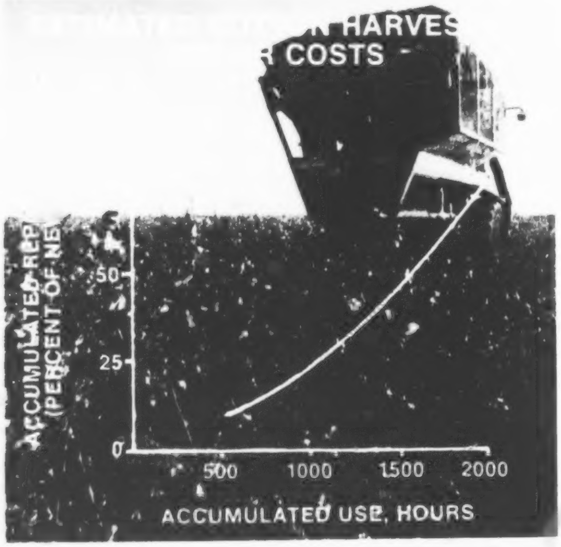
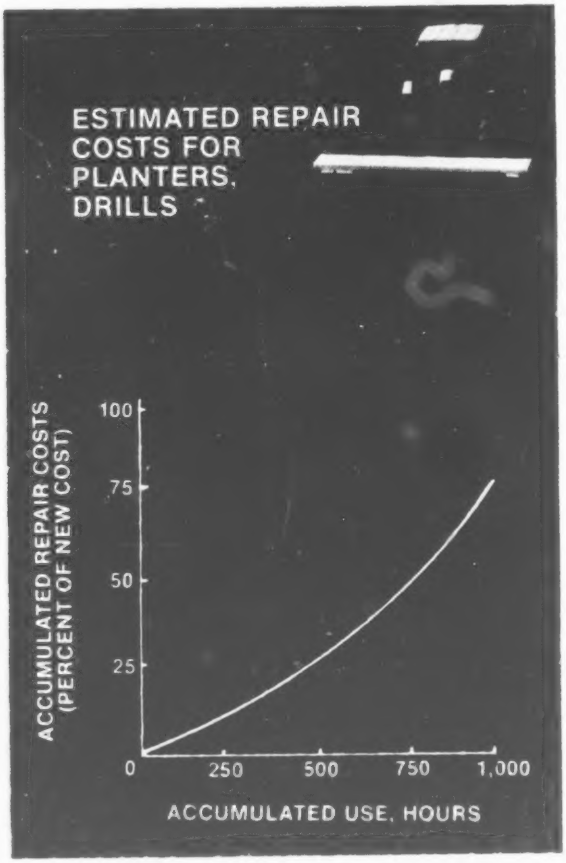


Fig. 15—Estimated Repair Costs For Cotton Harvesters

Fig. 16—Estimated Repair Costs For Planters And Drills



been developed. Information in Table 2 can be used in two meaningful ways:

1. To help estimate total costs of a specific type of machine.

2. To compare known repair costs against what is considered "average".

The table can also be used to compare estimates and actual repair costs.

Let's use an example to demonstrate the use of Table 2. Suppose $50,000 was paid for a 2-wheel-drive tractor five years ago. Assume that $4,368 has been spent over that time for repairs which include all service shop costs, parts installed and labor. The tractor hour meter shows 2,376 horus. Now, let's compare these repair costs to the estimate in Table 2.

According to Table 2, 2,376 hours is nearly one-fourth life. The table shows repair costs to average 9.8 percent at that point:

.098 × $50,000 = $4,900

In our example, $4,368 was spent, which is $532 less than estimated from Table 2. Unless unusual repair costs are incurred in the next 124 hours of use, the tractor will have close to average repair costs or just under that amount.

Cost per hour will be:

$\frac{\$4,368}{2,376}$ = $1.84 per hour

The estimate from the table is:

$\frac{\$4,900}{2,500}$ = $1.96 per hour

Information in Table 2 can also be used for estimating repair costs for a specific machine. Suppose it is planned to do custom work with a $20,000 self-propelled swather and an estimate of repair costs

TABLE 2

ACCUMULATED REPAIR COSTS* AS A PERCENT OF PURCHASE PRICE

	1/4 LIFE		1/2 LIFE		3/4 LIFE		FULL LIFE	
Machine	Accumulated Hours	Costs	Accumulated Hours	Costs	Accumulated Hours	Costs	Accumulated Hours	Costs
2- and 4-Wheel-Drive Tractors (Fig. 13)	2,500	9.8%	5,000	29.7%	7,500	56.8%	10,000	90.0%
Crawlers	4,000	8.7%	8,000	26.4%	12,000	50.5%	16,000	80.0%
Combines (Fig. 14)	750	5.77%	1,500	20.09%	2,250	41.68%	3,000	70.0%
All Cotton (Fig. 15) Harvesters Corn Heads Cornpickers	500	8.2%	1,000	24.7%	1,500	47.3%	2,000	75.0%
Planters (Fig. 16) Drills	250	8.2%	500	24.7%	750	47.3%	1,000	75.0%
Mowers	250	29.7%	500	73.1%	750	123.7%	1,000	180.0%
Plows Swathers (Fig. 17) Balers Balewagons Loose Hay Stack Wagons Forage Harvesters	500	13.2%	1,000	32.5%	1,500	55.0%	2,000	80.0%
Disks (Fig. 18) Chisel-Plows Field Cultivators	500	5.3%	1,000	18.7%	1,500	38.7%	2,000	65.0%

Sources: Adapted from data from Agricultural Engineering Department, University of Illinois, and the Agricultural Engineering Yearbook.

*Repair cost estimates in this table do not include the effect of inflation over the period of ownership.

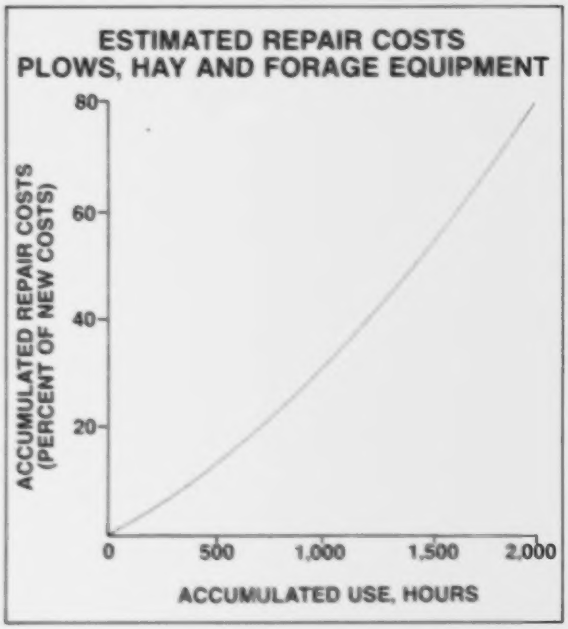
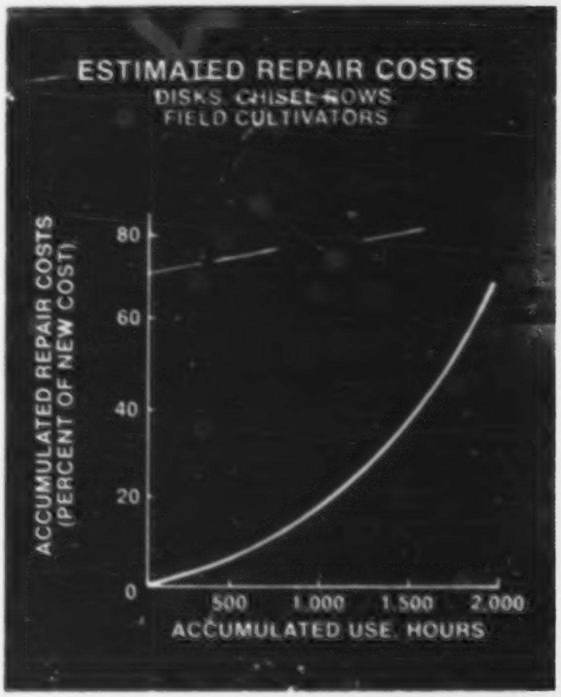


Fig. 17—Estimated Repair Costs For Plows, Hay And Forage Equipment

Fig. 18—Estimated Repair Costs For Disks, Chisels, Plows And Field Cultivators



is needed. Assume the swather will be used 2,000 hours, its approximate mechanical life. The swather operates at 5 acres per hour.

Information in Table 2 shows accumulated repair costs to be 80 percent of the new cost at 2,000 hours. Because 80 percent of $20,000 is $16,000 or $8.00 per hour, repair costs would be $1.60 per acre ($3.95 per hectare) at 5 acres (2 hectares) per hour.

SUMMARY

Repair costs can usually be classified as an operating cost. Repairs are an important part of machinery management as they are necessary to maintain a machine's reliability and keep it performing at maximum capacity.

Reliability is important to good management because it expresses the amount of confidence placed in a machine to perform without unplanned time losses.

It is more important than ever to avoid or to be able to quickly repair machine breakdowns. Because of the larger machine size on farms today and the resulting increased productivity, good management of repairs and the resulting increase in reliability is well justified.

There are four main types of repairs:

1. *Routine wear*
2. *Accidental breakage or damage*
3. *Repairs due to operator neglect*
4. *Routine overhauls*

It pays to get machines ready ahead of time. Make all necessary repairs and have the machine adjusted and ready to go before it is needed.

CHAPTER QUIZ

1. What are the four reasons for repairs?

2. What is the main purpose of repairs?

3. Define "reliability".

4. How much would you expect to spend for repairs during the first 2500 hours of use for a $50,000 tractor?

5. (Multiple choice.) If a cotton picker costs $40,000 and harvests 3000 bales in 1500 hours, what is the average repair cost per bale?

a) $24.64

b) $8.40

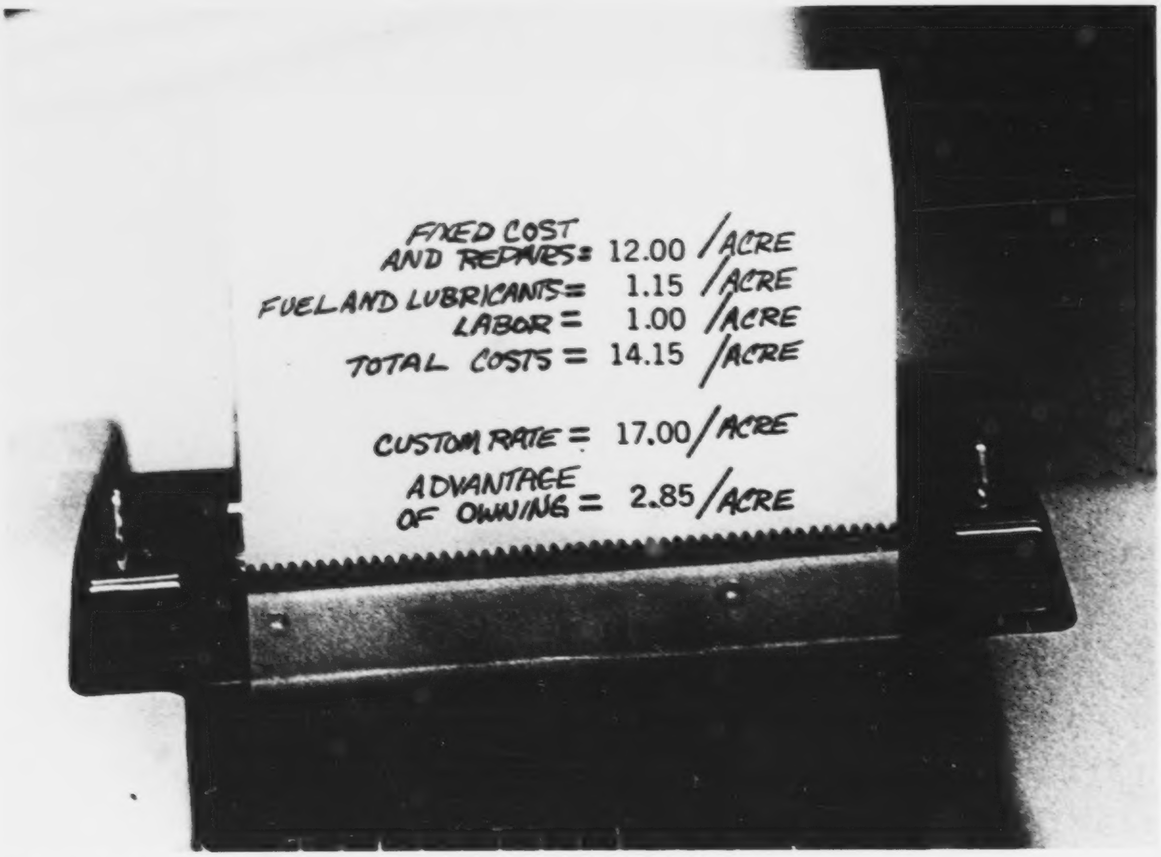
c) $10.00

d) $5.04

e) $6.31

9

Total Costs for Machines and Operations



FIXED COST AND REPAIRS = 12.00 /ACRE
FUEL AND LUBRICANTS = 1.15 /ACRE
LABOR = 1.00 /ACRE
TOTAL COSTS = 14.15 /ACRE

CUSTOM RATE = 17.00/ACRE
ADVANTAGE OF OWNING = 2.85/ACRE

Fig. 1—To Make Important Management Decisions, Know How To Estimate Total Cost

INTRODUCTION

In the past three chapters, methods for estimating fixed costs, operating costs and repair costs were presented. These three costs will now be combined in this chapter to estimate *total costs*. Accurate total-cost estimates are the basis for important management decisions and will be used throughout the following chapters (Fig. 1).

This chapter will provide information on how to estimate total costs for the use of an individual machine, and for operations involving a combination of two or more machines. Costs for entire machine systems can be estimated once the procedure for estimating costs for specific machines is mastered.

COSTS FOR INDIVIDUAL MACHINES

Some of the tables in the Appendix have been developed for making cost estimates. These tables are

Fig. 2—Accurate Records Provide The Best Information For Cost Estimates

ESTIMATING COSTS FOR
2- AND 4-WHEEL-DRIVE TRACTORS

Useful life = 10,000 hours   Repair costs = $\$1,000 \times .9 \times .000631 \times (\%\ \text{life})^{1.6}$
Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

Hours of annual use	(Age, Years) 1	2	3	4	5	6	7	8	9	10
400	$1.176	$0.745	$0.598	$0.523	$0.475	$0.442	$0.418	$0.398	$0.382	$0.369
450	$1.047	$0.666	$0.536	$0.470	$0.429	$0.400	$0.379	$0.362	$0.349	$0.338
500	$0.945	$0.603	$0.487	$0.428	$0.392	$0.367	$0.349	$0.334	$0.323	$0.313
550	$0.861	$0.551	$0.447	$0.395	$0.362	$0.340	$0.324	$0.312	$0.302	$0.293
600	$0.792	$0.509	$0.414	$0.367	$0.338	$0.318	$0.304	$0.293	$0.285	$0.278
650	$0.733	$0.473	$0.386	$0.343	$0.317	$0.300	$0.287	$0.278	$0.271	$0.265
700	$0.683	$0.442	$0.363	$0.323	$0.300	$0.284	$0.273	$0.265	$0.259	$0.254
750	$0.639	$0.416	$0.342	$0.306	$0.285	$0.271	$0.262	$0.254	$0.249	$0.245
800	$0.601	$0.392	$0.325	$0.292	$0.272	$0.260	$0.251	$0.245	$0.241	$0.237
850	$0.568	$0.372	$0.309	$0.279	$0.261	$0.250	$0.243	$0.237	$0.234	$0.231
900	$0.538	$0.354	$0.296	$0.268	$0.252	$0.242	$0.235	$0.231	$0.228	$0.225
950	$0.511	$0.338	$0.284	$0.258	$0.243	$0.234	$0.229	$0.225	$0.222	$0.221
1,000	$0.488	$0.324	$0.273	$0.249	$0.236	$0.228	$0.223	$0.220	$0.218	$0.217
1,050	$0.466	$0.311	$0.263	$0.241	$0.229	$0.222	$0.218	$0.215	$0.214	*
1,100	$0.447	$0.300	$0.255	$0.234	$0.223	$0.217	$0.214	$0.212	$0.211	*
1,150	$0.429	$0.289	$0.247	$0.228	$0.218	$0.213	$0.210	$0.208	*	*
1,200	$0.413	$0.280	$0.240	$0.222	$0.213	$0.209	$0.206	$0.205	*	*

* No cost shown since total use is greater than expected life of the machine.

Fig 3—Use The Tables In The Appendix To Estimate Costs For Specific Situations

intended to be used only as one source of cost estimates. Your own accurate records would be a better source than these tables, except for a new type of machine you are thinking of buying (Fig. 2). The cost tables in the Appendix are a combination of information in Chapters 6, 7 and 8, except—fuel, lubricants and labor costs are not included and must be figured separately. These tables include fixed costs and repair costs.

USING MACHINE COST TABLES

To illustrate how to use the machine cost tables, look at the tractor costs shown in Table 1 of the Appendix. Costs will be calculated for a 100 hp diesel tractor with a list price of $36,000. It is used 500 hours a year for five years, and has a diesel engine with fuel cost at $1.00 per gallon ($0.26 per liter).

In Table 1 of the Appendix (the table of accumulated average fixed and repair costs for 2- and 4-wheel-drive tractors), look at the cost figure shown opposite 500 hours per year under the five-years-of-use column. This figure is $0.392 (Fig. 3). At the top of the table note that cost figures are for $1,000 of new cost. The costs included in these tables are:

- **Depreciation**
- **Taxes**
- **Shelter**
- **Interest**
- **Insurance**
- **Repairs**

Because the tractor had a new cost of $36,000, it would have 36 cost units of $1,000:

$36,000 (new cost) divided by $1,000 = 36 cost units

Therefore, multiply the cost figure from the table by 36:

36 cost units x 0.392 = $14.11 per hour of use

Fig. 4—For Machines With Engines, Fuel And Lubricant Costs Must Also Be Included In Cost Estimates

With five years of use at 500 hours per year, the accumulated use of the $30,000 tractor would be 2,500 hours. Total expenditures for repairs plus all fixed costs would be:

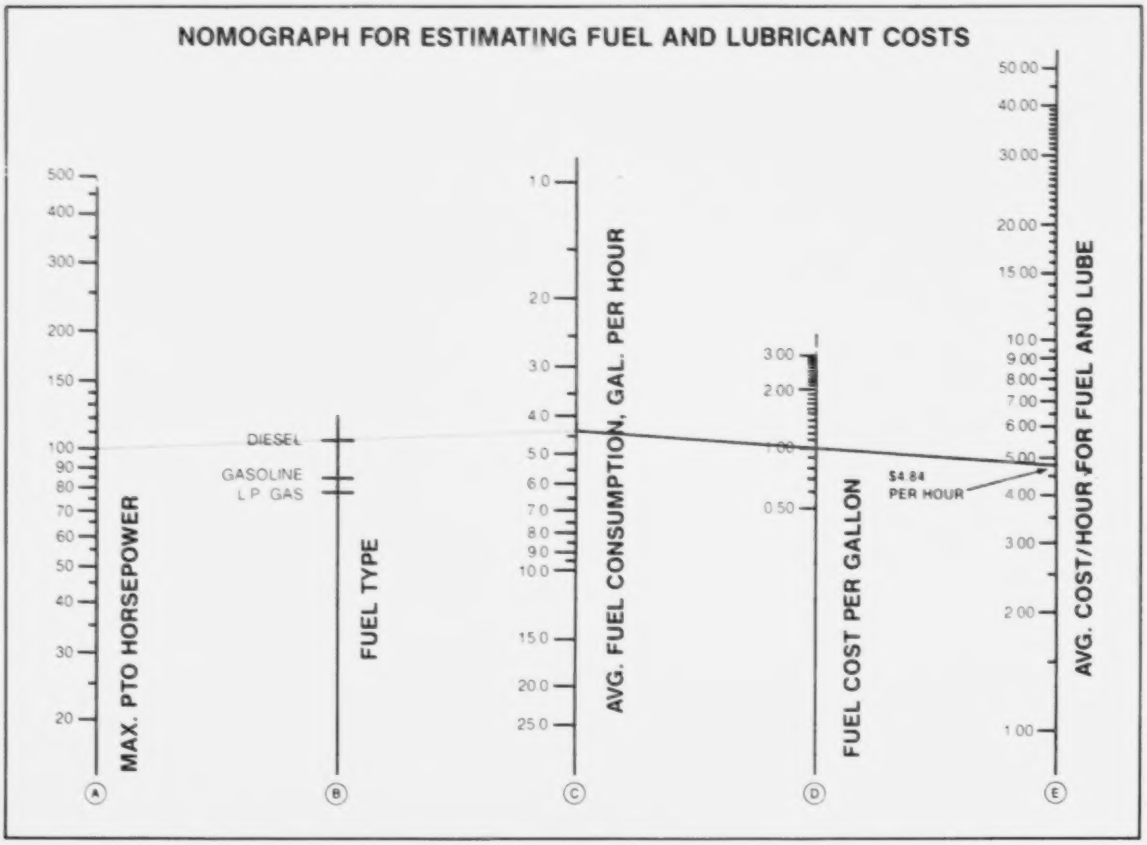
2,500 hours x $14.11 per hour = $35,275

ESTIMATING MACHINE COST

All of the cost tables in the Appendix can be used in the same way. Fuels and lubricants also must be computed for tractors and implements that are engine driven (fig. 4). To refresh your memory, study the methods for estimating fuel and lubricant costs in Chapter 7.

For diesel engines, the average fuel consumption is 0.044 times maximum PTO horsepower. A 100-horsepower diesel-engine tractor would use 4.4 gallons per hour (100 hp x 0.044) as an average for the whole year. The average fuel consumption for diesel engines, using metric values is 0.223 times maximum PTO kilowatt rating (see Appendix Table 13). A 75-kilowatt diesel-engine tractor would use 16.7 liters per hour (75 kW x 0.223) as an average for the whole year.

Fig. 5—This Nomograph From Chapter 7 Can Also Be Used To Estimate Fuel And Lubricant Costs



NOMOGRAPH FOR ESTIMATING FUEL AND LUBRICANT COSTS

Now calculate fuel and lubricant costs (fig. 5):

Fuel costs = 4.4 gallons per hour x $1.00 per gallon
= $4.40 per hour
Ⓜ Fuel cost = 16.7 liters per hour x $0.26 per liter
= $4.40 per hour
Lubricant costs = 10 percent of fuel costs
= 0.10 x $4.40 = $.44 per hour
Total fuel and lubricant costs = $4.40 + $0.44
= $4.84 per hour

For 2,500 hours of use, the total fuel and lubricant cost would be $12,100 ($4.84 x 2,500).

Including fixed costs, repair costs and operating costs, the average costs for the $36,000, 100-horsepower (75 kilowatt) tractor over a five-year period would be:

Fixed costs plus repairs = $14.11 per hour

Fuel and lubricant costs = $4.84 per hour

TOTAL = $18.95 per hour

Not including labor, average annual costs are:

500 hours per year x $18.95 per hour = $9,475

Thus the average total costs for the tractor after five years of use at 500 hours per year would be $18.95 per hour, not including labor (Fig. 6).

Try estimating the average costs at the end of each of the first four years for the same tractor (Fig. 7). The answers should be:

Year 1 = $38.86 per hour

Year 2 = $26.55 per hour

Year 3 = $22.37 per hour

Year 4 = $20.25 per hour

In using the tables in the Appendix for estimating costs, remember that only *repair, depreciation, taxes, shelter, insurance* and *interest costs* are included. For the final total costs, add fuel and lubricant costs plus labor if it is to be included also.

Let's try another example of calculating total costs.

What is the average cost for a $6,000 moldboard plow after 10 years with 100 hours per year of use? Capacity is 3.0 acres (1.2 hectares) per hour.

Shown in Table 7 of the Appendix is a cost of $1.588 per hour per $1,000 of cost of the plow (Fig. 8). Round this figure off to $1.59.

Dividing the cost ($6,000) by 1,000 gives a factor of 6.0 — the number of $1,000 units.

Multiplying the 6.0 units by $1.59 per hour provides an answer of 9.54 per hour, the average cost per hour for the plow. The plow by itself would not have any fuel or lubricant costs (except possibly a small lubricant cost).

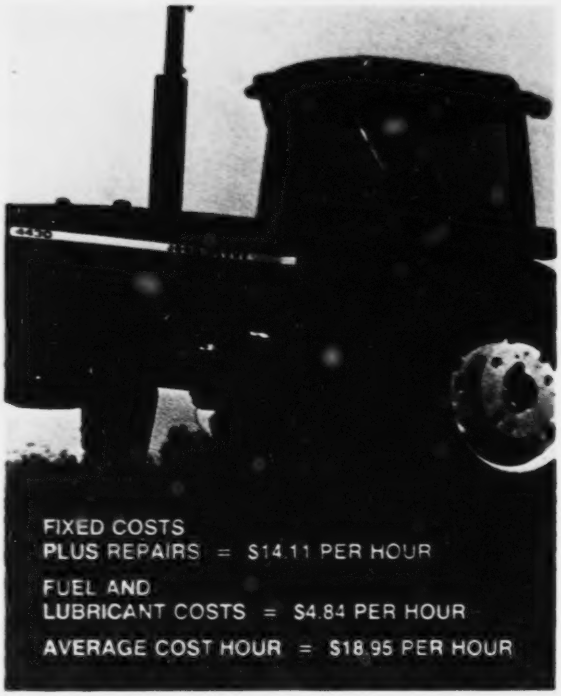
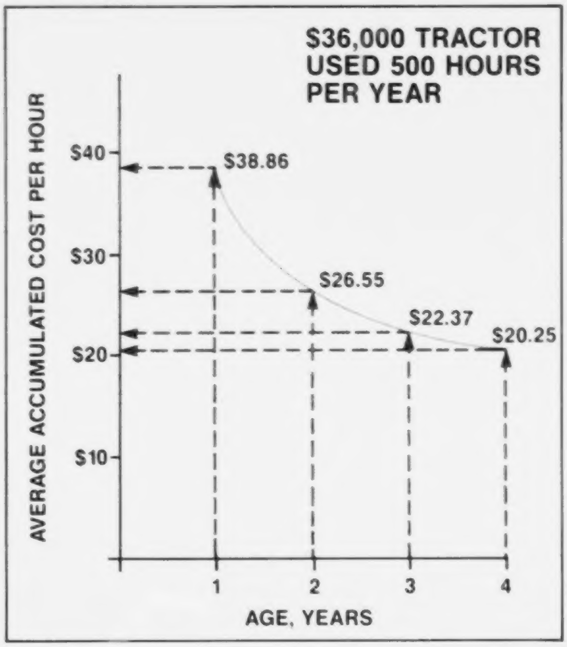
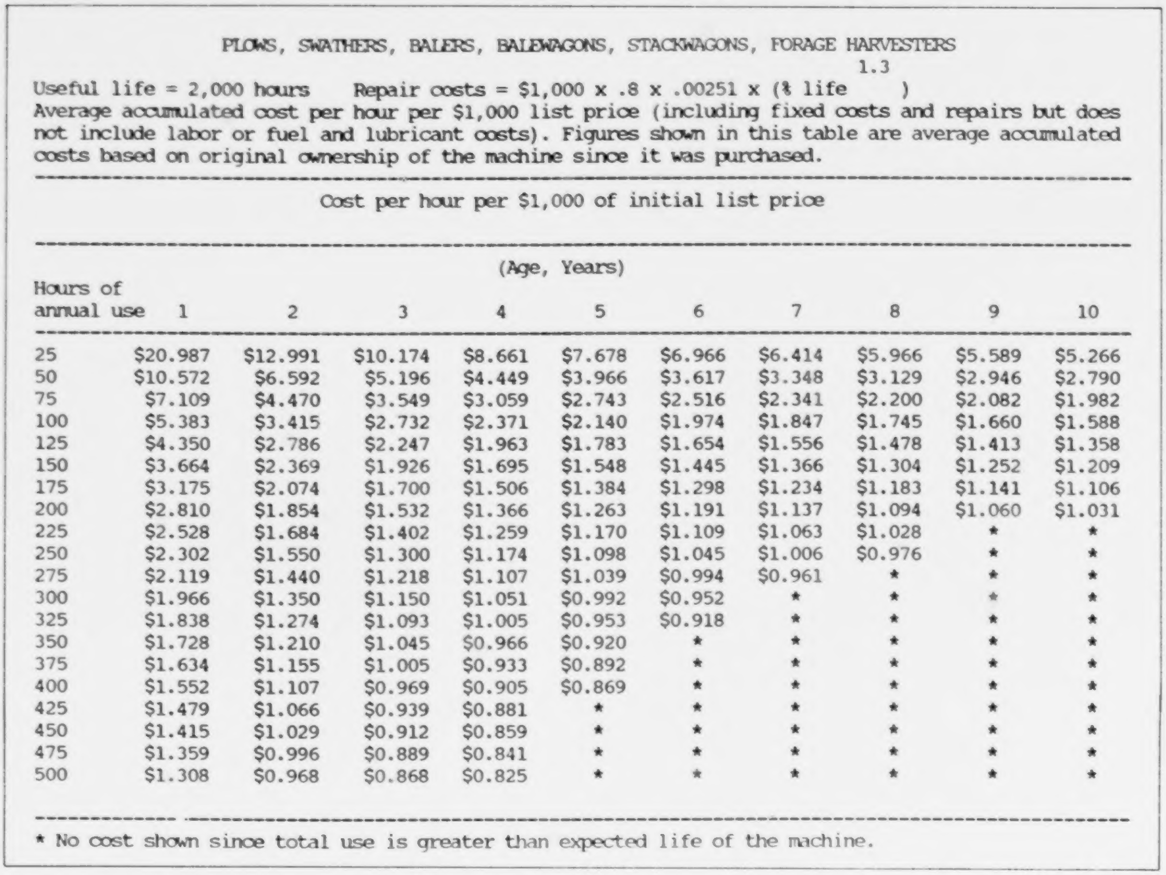

FIXED COSTS
PLUS REPAIRS = $14.11 PER HOUR
FUEL AND
LUBRICANT COSTS = $4.84 PER HOUR
AVERAGE COST HOUR = $18.95 PER HOUR

Fig. 6—Total Costs For A $36,000 Tractor Used 2,500 Hours In Five Years

Fig. 7—Average Cost Per Hour For A $36,000 Tractor Used 500 Hours Per Year





PLOWS, SWATHERS, BALERS, BALEWAGONS, STACKWAGONS, FORAGE HARVESTERS

Useful life = 2,000 hours   Repair costs = $1,000 x .8 x .00251 x (% life$^{1.3}$)
Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

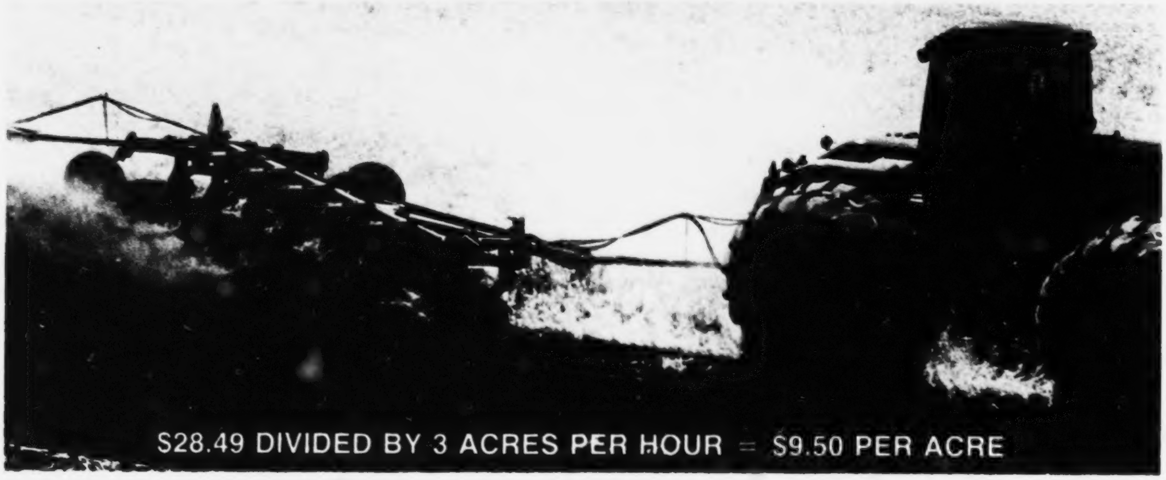
Cost per hour per $1,000 of initial list price

Hours of annual use	(Age, Years) 1	2	3	4	5	6	7	8	9	10
25	$20.987	$12.991	$10.174	$8.661	$7.678	$6.966	$6.414	$5.966	$5.589	$5.266
50	$10.572	$6.592	$5.196	$4.449	$3.966	$3.617	$3.348	$3.129	$2.946	$2.790
75	$7.109	$4.470	$3.549	$3.059	$2.743	$2.516	$2.341	$2.200	$2.082	$1.982
100	$5.383	$3.415	$2.732	$2.371	$2.140	$1.974	$1.847	$1.745	$1.660	$1.588
125	$4.350	$2.786	$2.247	$1.963	$1.783	$1.654	$1.556	$1.478	$1.413	$1.358
150	$3.664	$2.369	$1.926	$1.695	$1.548	$1.445	$1.366	$1.304	$1.252	$1.209
175	$3.175	$2.074	$1.700	$1.506	$1.384	$1.298	$1.234	$1.183	$1.141	$1.106
200	$2.810	$1.854	$1.532	$1.366	$1.263	$1.191	$1.137	$1.094	$1.060	$1.031
225	$2.528	$1.684	$1.402	$1.259	$1.170	$1.109	$1.063	$1.028	*	*
250	$2.302	$1.550	$1.300	$1.174	$1.098	$1.045	$1.006	$0.976	*	*
275	$2.119	$1.440	$1.218	$1.107	$1.039	$0.994	$0.961	*	*	*
300	$1.966	$1.350	$1.150	$1.051	$0.992	$0.952	*	*	*	*
325	$1.838	$1.274	$1.093	$1.005	$0.953	$0.918	*	*	*	*
350	$1.728	$1.210	$1.045	$0.966	$0.920	*	*	*	*	*
375	$1.634	$1.155	$1.005	$0.933	$0.892	*	*	*	*	*
400	$1.552	$1.107	$0.969	$0.905	$0.869	*	*	*	*	*
425	$1.479	$1.066	$0.939	$0.881	*	*	*	*	*	*
450	$1.415	$1.029	$0.912	$0.859	*	*	*	*	*	*
475	$1.359	$0.996	$0.889	$0.841	*	*	*	*	*	*
500	$1.308	$0.968	$0.868	$0.825	*	*	*	*	*	*

* No cost shown since total use is greater than expected life of the machine.

Fig. 8—A Different Table Is Required For Estimating Costs For Plows

Fig. 9 — Total Cost For the Plowing Operation In This Situation Is $28.49 Per Hour Or $9.50 Per Acre ($23.74 Per Hectare)



ESTIMATING TRACTOR-MACHINE COSTS

Now that the cost examples for the $36,000 tractor and the $6,000 plow have been presented, we can combine the two for estimating the total cost of an operation such as plowing.

Tractor cost = $18.95 per hour

Plow cost = $9.54 per hour

Average plowing cost = $28.49 per hour

If average capacity for the plowing operation is 3.0 acres per hour, $28.49 divided by 3.0 acres per hour provides an answer of $9.50 as the cost per acre (Fig. 9). In metric equivalents, average capacity is 1.2 hectares per hour equals $23.74 as the cost per hectare. But using these cost tables involves two important assumptions.

One assumption is the *average annual use;* the other is the *age of the machine* or how long it is planned to own the machine. In the previous example, we assumed the tractor is owned five years with a use of 500 hours per year.

How would the average cost per hour be changed for the tractor if it is used 800 hours per year for five years? Go back to Table 1 in the Appendix and calculate the tractor costs again.

Information in the table shows fixed cost plus repairs to be $0.272 per hour per $1,000 list price.

$36,000 divided by $1,000 = 36 cost units

36 units x $0.272 = $9.79 per hour of fixed cost plus repairs

Adding the fuel and lubricant costs of $4.84 per hour to repairs and fixed costs, we can add up total costs as follows:

Fixed costs plus repairs = $9.79 per hour

Fuel and lubricant costs = $4.84 per hour

TOTAL COSTS = $14.63 per hour

Increasing tractor use to 800 hours per year in this example cuts average costs from $18.95 per hour to $14.63 per hour (Fig. 10). When added to the plow costs, assuming annual use on plow remains at 100 hours per year, we arrive at a sum of total costs:

Tractor = $14.63 per hour

Plow = $ 9.54 per hour

Total Operation Costs = $24.17 per hour

At 3.0 acres per hour, plowing costs would be $8.06 per acre ($24.17/3.0 acres), not including labor.

At 1.2 hectares per hour, plowing costs would be $20.14 ($24.17/1.2 hectares), not including labor.

These examples show that the more a machine is used, the lower the cost per unit of use. Increasing tractor use from 500 to 800 hours per year lowered costs from $28.49 to $24.17 per hour for a savings of $4.32 per hour. Fixed

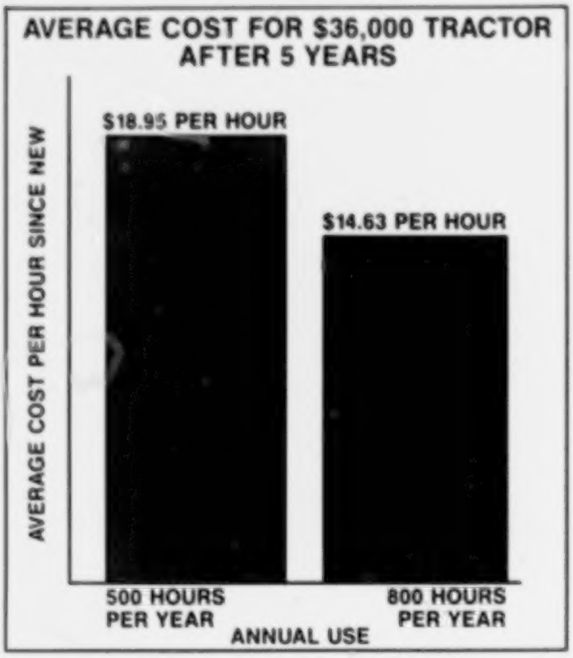
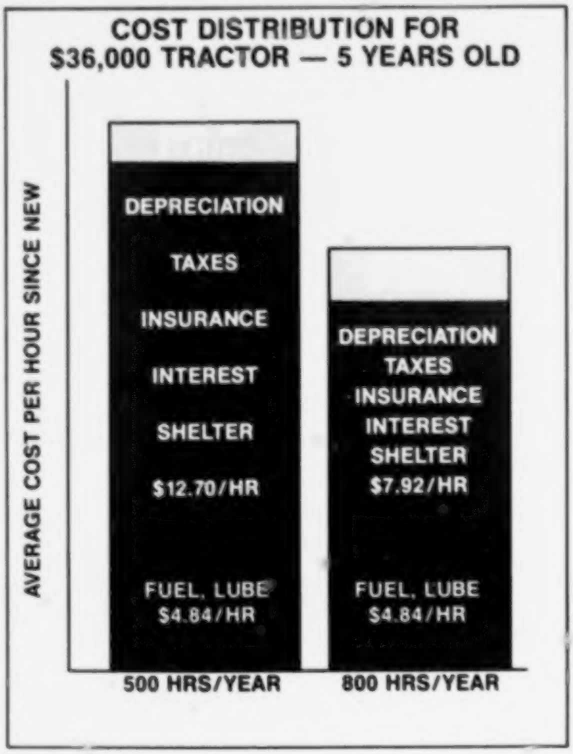


Fig. 10—Increasing Annual Use Reduces Cost Per Hour

Fig. 11—How Various Costs Are Affected By Amount Of Use



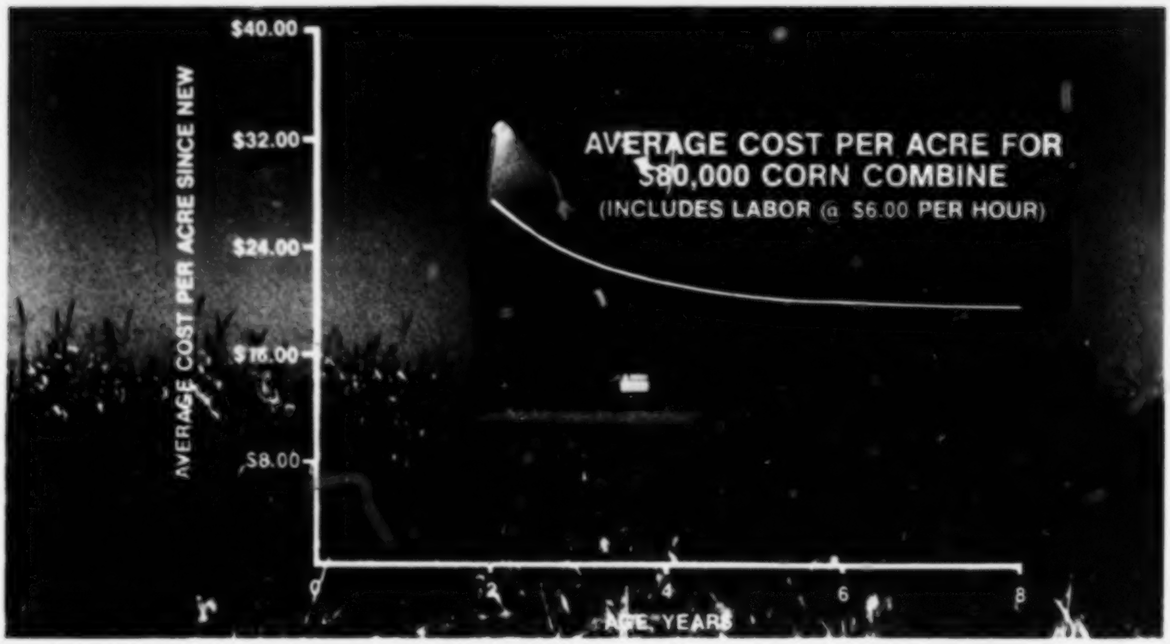


Fig. 12—The Effect Of Age On Average Costs For An $80,000 Corn Combine

costs tend to remain constant on an annual basis while repair, fuel and lubricant costs are almost directly proportional to the amount of annual use (Fig. 11).

ESTIMATING COSTS FOR COMBINES

One of the most widely used machines is a self-propelled combine, so we will use this machine to show another important principle—estimating combine costs.

Suppose we want to determine the average cost per acre for an $80,000 corn combine that has a capacity of 4.0 acres (1.6 hectare) per hour. This time we will include labor at $6.00 per hour. Diesel costs $1.00 per gallon ($0.26 per liter).

Assuming an annual use of 250 hours per year, what is the average cost per acre at the end of two, four, six and eight years?

Data in Table 3 in the Appendix show fixed costs plus repairs. The costs for this combine can be determined as shown in Table 1.

Although the change is not as drastic, the effect of the length of ownership is illustrated in this example (Fig. 12).

SYSTEM COSTS

We have shown how to estimate total costs for a sin-

TABLE 1

COMBINE COSTS (YEARS)

	Age, Years			
	2	4	6	8
Fixed cost plus repairs, hours per $1,000 (From Table 3, Appendix)	$ 1.146	$ 0.882	$ 0.792	$ 0.748
Fixed cost plus repairs, $80,000 combine	$ 91.68	$70.56	$63.36	$59.84
Labor cost/hour	$ 6.00	$ 6.00	$ 6.00	$ 6.00
TOTAL for fixed cost plus labor per hour	$ 97.68	$76.56	$69.36	$65.84
Fuel and lubricant cost/hour	$ 10.80	$10.80	$10.80	$10.80
TOTAL	$108.48	$87.36	$80.16	$76.64
AVERAGE COST/ACRE	$ 27.12	$21.84	$20.04	$19.16

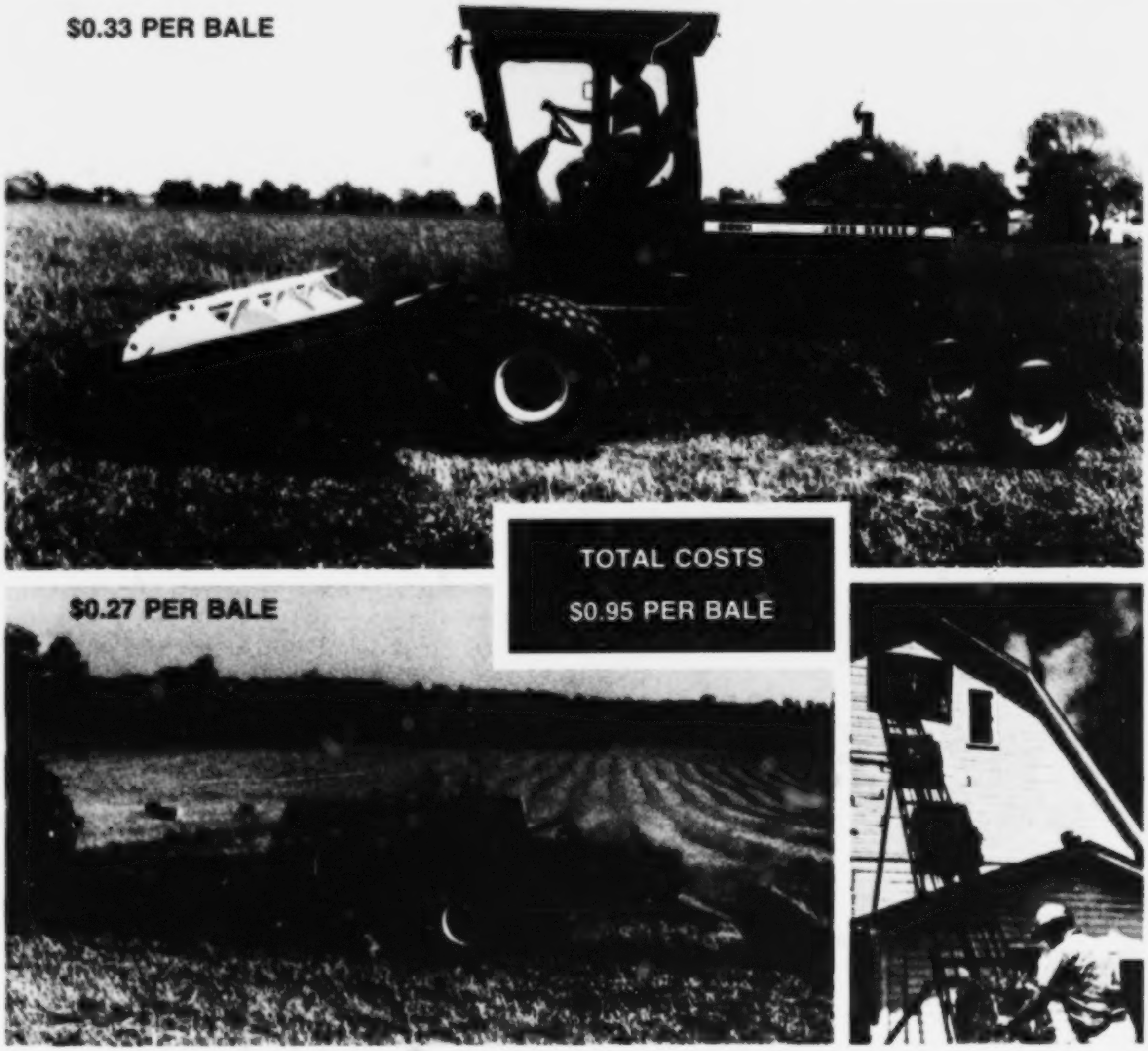


Fig. 13—Costs For Entire Systems Can Be Estimated With Information In This Book

gle machine or tractor-machine combination. Next, we will look at a complete system in Table 2 to show the division of costs and total cost for an entire operation. The last section of this book will provide a better understanding of calculating total costs for a complete operation.

The example shown in Table 2 is for baled hay operation (Fig. 13).

Assume the yield is 1.0 ton per acre (30 bales = 1.0 ton), labor is $6.00 per hour, baling requires a tractor at $3.25 per hour, swathing requires 0.55 gallons of diesel per acre. Diesel is $1.00 per gallon. Wire for bales costs $.20 per bale.

TABLE 2

HAY BALING COSTS

Operation	Capacity	New Cost	Hours Per Year	Years To Own
Self-propelled swather	5 A/hr (2 ha/hr)	$30,000	200	4
Baling	7 A/hr (2.8 ha/hr)	$ 8,500	200	4
Hauling	(Custom hired at 35¢ per bale)			

```
                         COST SUMMARY
---------------------------------------------------------------

           Cost/    Cost/     Cost/     Cost/     Cost/

OPERATION  Hour     Acre      HA        Ton       Bale

Swathing   $50.00   $10.00    $25.00    $10.00    $0.33

Baling      62.86     8.98     22.45      8.98     0.27

Hauling     ---      10.50     25.95     10.50     0.35
                    -------   ------    -------   ------
Total               $29.48    $73.40    $29.48    $0.95
```

Ⓜ Assume the yield is 2.25 metric tons per hectare (33 bales = 1.0 metric tons), labor is $6.00 per hour, baling requires a tractor at $3.25 per hour, swathing requires 5.1 liters per hectare. Diesel is $0.26 per liter.

SUMMARY

This chapter deals basically with estimating total costs for machines, operations and systems. Accurate records are the best source of material for estimating costs, but cost tables are provided in the Appendix for estimating machine costs. The costs included in these tables cover:

- **Depreciation**
- **Taxes**
- **Shelter**
- **Interest**
- **Insurance**
- **Repairs**

But when estimating total costs for machines, *fuel* and *lubricant costs* must also be included. Methods for estimating fuel and lubricant costs were provided in Chapter 7.

Another cost that should be included is labor. This cost can be easily added in for each situation. With fuel, lubricant and labor costs added to the fixed costs and repair costs included in the tables, the *total cost* for an entire system can be calculated. Estimating total cost for a system is a basic skill for machinery management and an integral part of the following chapters.

Why It Is Important To Know Total Costs

Every decision relating to machinery should be based on accurate total cost estimates. For Example, if you know the average cost per hour or acre for every machine then you can use the purchase price of the machine to determine whether your costs are declining or increasing. You also can use this information as the basis for deciding when to trade. If you know what is happening to repair costs and how they are affecting total costs, then you can decide if it is better to trade or to continue to keep up your repair program. Perhaps knowledge of total costs is of greatest importance if you are comparing ownership of a machine to hiring a custom operator.

CHAPTER QUIZ

1. Think of and list three important machinery management decisions you could make if you know how to make an accurate cost estimate.

2. What costs are included in the "cost per hour" tables?

3. What is the average of fixed costs and repairs per hour of use for each $1,000 of new cost for a tractor used 800 hours per year and that is four-years old? (Use tables in Appendix.)

4. What is the average total cost per hour for a $30,000, 80-horsepower tractor after 4 years if it is used 800 hours per year? (Assume diesel fuel at $1.00 per gallon.)

5. If labor is $6.00 per hour, what is the average cost per hour for a $25,000 self-propelled swather if:

- It is 4-years old.
- It is used on 500 acres per year, and operates at

5. If labor is $6.00 per hour, what is the average cost per hour for a $30,000 self-propelled swather is:

- It is 4-years old.
- It is used on 500 acres per year, and operates at 5.0 acres per hour.
- It has a diesel engine that averages 5.2 gallons per hour.
- Diesel costs $1.00 per gallon.
- Lubricant costs equal 10 percent of fuel costs.

6. What is the average cost per acre for a self-propelled combine with a cost of $100,000 if it is used for 700 acres of soybeans and 700 acres of corn a year? Labor is $6.00 an hour. Diesel fuel is $1.00 a gallon. Lubricant costs equal 10 percent of fuel costs. Capacity for the combine is 4.5 acres per hour in soybeans and 4 acres per hour in corn. Assume that the combine will be owned 8 years, with an annual use of 350 hours. (Hint — You will need to use some of the tables and information in previous chapters to solve this problem)

7. What are three ways to lower machinery cost per acre?

III

Managing Machinery

Deciding When To Trade 10
Considering Future Capacity Needs 11
Calculating Custom Work Costs 12
Comparing Ownership, Leasing and Rental Costs 13
Starting Machinery Management 14

MANAGING MACHINERY

In the first five chapters, basic information was presented about machine performance, speed, field efficiency and capacities. Information was also provided on how to match power units and machines for satisfactory field operation.

The four chapters in Section II showed how some simple, but meaningful, cost estimates can be made for individual machines or combinations of machines.

In the next section, this background information will be used to show how to make those important, money-making decisions. But it will not be a matter of looking up the right answer for every tough question that comes along. Many solutions have to be thought through and calculated.

Important machinery management decisions are not easy. In fact, most authorities agree that machinery management decisions are harder to pin down than most other decisions related to farming.

Most machinery management problems can be solved by doing the following:

- Accurately estimate total working time that is available for major field operations
- Determine effective field capacity of machines
- Match power units to machines
- Predict costs accurately for any machine application

In these final chapters, it is demonstrated how to put these basic parts together so decisions can be made. While reference data presented is intended to be as accurate as any available, it may not always be perfect for each situation. But that's one of the advantages to having a knowledge of the more basic information. It is better preparation for adapting the reference information to solve specific problems.

Carefully follow through with the sample problems in these final chapters. Doing so will greatly improve machinery management ability or provide a good review for those more experienced as machinery managers.

10

Deciding When to Trade

INTRODUCTION

Deciding when to trade machinery is the first of four steps involved in putting together the information in previous chapters. It is an important chapter because, just as most people like new possessions, most farmers like new machinery.

Although it would be convenient to trade for a new machine every 2 or 3 years, few farmers use them enough to justify the cost. However, if machinery is kept too long, repair costs rise and machines may break down when needed most. For the best profits, use facts, not guesswork, to decide when to trade machinery (Fig. 1).

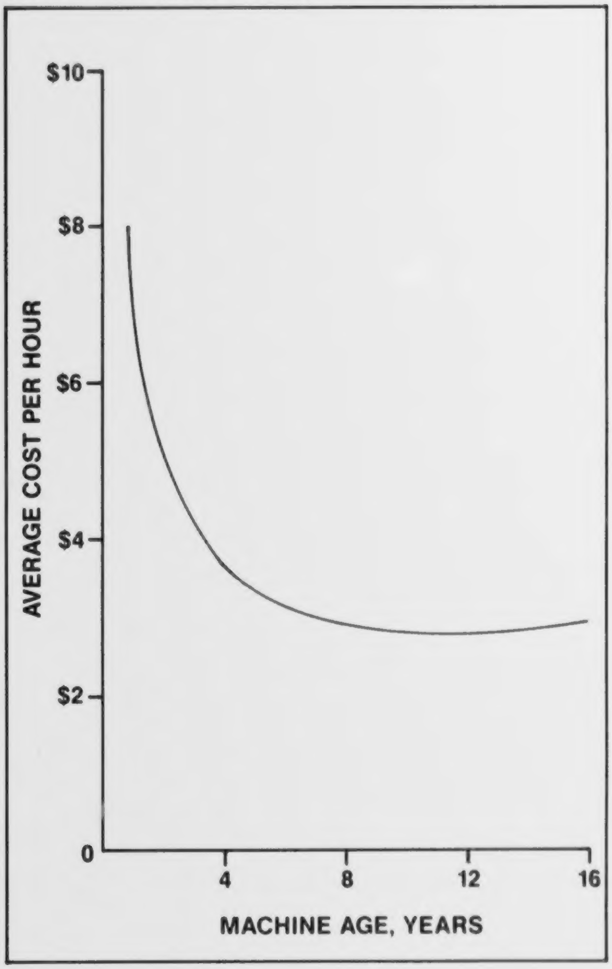
Fig. 1—Determining When To Trade Should Be Based On Facts For The Best Profits

ESTABLISHING TRADING GUIDELINES

Good guidelines are important for making management decisions on when to trade machinery. Five important reasons for trading a machine are:

1. The accumulated average cost per unit of use has reached its lowest point and is increasing.
2. The machine is obsolete in comparison to new models.
3. The machine has lost its reliability, meaning it is no longer dependable.
4. The machine is worn out.
5. The increase in the size of an operation makes a machine too small for timely operations.

Fig. 2—One Basis For Trading Is When The Average Cost Per Unit Of Use Has Reached Bottom And Starts To Increase



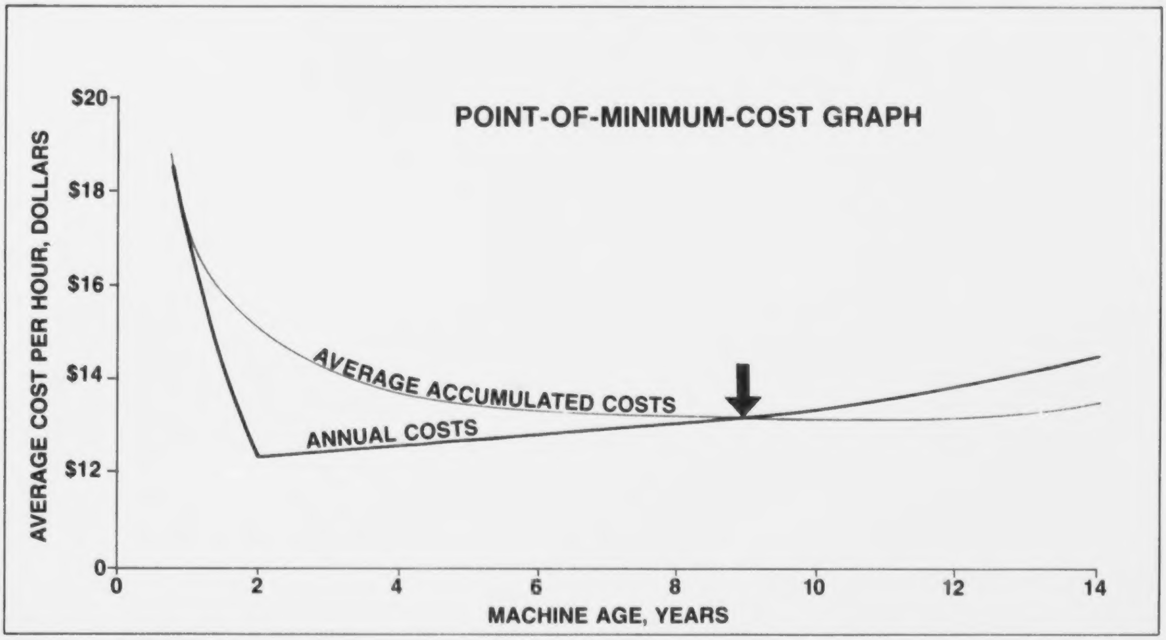


Fig. 3—According To The Point-Of-Minimum-Cost Theory. The Time To Trade Is When Annual Costs Are Equal To The Accumulated Average Cost Per Unit Of Use

In all cases investment credit or other tax credits need to be included when considering the purchase of new machinery. It is impossible to address these issues in this book due to the constant changes in tax laws. Instead it is suggested that you first learn how to make an accurate cost analysis, and then determine how it is affected by tax laws. When you do this you will have a strong foundation on which you can make decisions.

AVERAGE COST PER UNIT OF USE

Average accumulated costs are those that include all of the costs that are incurred since the date of ownership. On the other hand, annual costs refer only to the costs for one year. All of the annual costs added together would give the accumulated costs.

Typical average accumulated costs for tractors and machinery are shown in Fig. 2. Notice how the average cost per hour (since the time of purchase) begins high, decreases rapidly for a few years, then gradually decreases. With typical operating conditions, the point of minimum costs will seldom occur before the tenth year.

In Chapter 6, we saw that fixed costs decrease with age. When the average annual repair costs start increasing faster than average annual fixed costs are decreasing, it means the accumulated average cost curve will start rising.

The annual cost curve as well as the accumulated average cost curve for a $35,000 tractor used 1,000 hours a year are shown in Figure 3. The curves intersect in our example at about the ninth year.

Theoretically, the time to trade is when the annual cost starts to exceed the average cost over the entire time the machine has been owned. This rule is all right in cases where the annual use is high and extensive repairs would make the annual costs quite high.

But, there are two good reasons why it is not advisable to always try to trade when annual cost equals accumulated average cost.

In the first place, tractors having an annual use of less than 800 hours will not reach their point of minimum costs until well beyond the tenth year.

In normal times, planning to own any machinery or tractor more than ten years can be risky due to the danger of obsolescence, high repair bills, and loss of reliability. However, when you are financially squeezed, or simply cannot afford to trade, then the best alternative is to continue to own. In this case you must take care to properly maintain the machine (Fig. 4).

Fig. 4 — Older machines need better care, repair and maintenance.

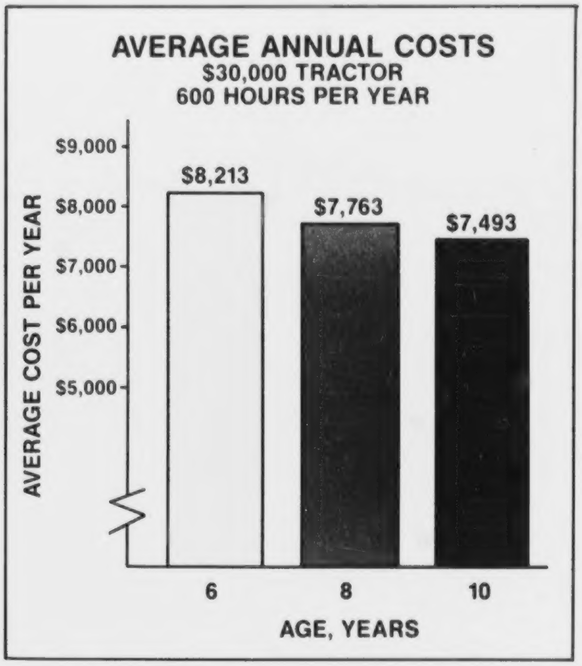


Fig. 5—Cost Savings From Lengthy Ownership May Not Be Justified Due To Increased Odds Of Loss Of Reliability

Second, average accumulated costs tend to flatten after eight to ten years (Fig. 5). The difference in the average cost per hour for a $30,000 tractor with 600 hours a year of use is not very great. At 600 hours per year, the difference in average annual costs is only $270 a year ($0.45 per hour).

MACHINE OBSOLESCENCE

Machines, and to some extent tractors, can become obsolete before they are worn-out completely. Obsolete means a machine is no longer as well suited for the work to be accomplished as newer machines or models.

Tractors are basically power units and therefore do not become obsolete as fast as combines, balers, swathers and other machines (Fig. 6).

Machines can be considered to become obsolete in three ways:

1) A new model of the same machine may have a design change resulting in better efficiency and increased capacity.

2) Increased horsepower and the resulting capacity may be needed due to expanded field operations or less labor available.

3) A new concept may be introduced. For example, the mechanical stack wagons and the large round balers are relatively new machine concepts in hay handling.

MACHINE RELIABILITY

When a machines loses its reliability, it is no longer dependable for completing the job in the time available. Most experts agree it is difficult to repair a machine and economically regain the proper level of reliability once it has started having periodic breakdowns.

If a machine starts breaking down often, the amount of repairs needed to restore an acceptable level of reliability may be prohibitive. This is especially true for the larger, more complex machines.

It is difficult to determine exactly when a machine is no longer reliable. The greater the amount of annual use or the larger the capacity of the machine, the higher the reliability must be (Fig. 7).

By maintaining a high level of reliability through good maintenance and correct operation, you can count on a machine's use during 95 percent or more of the available working time.

Fig. 6—Machines Can Become Obsolete Before They Are Worn Out

Fig. 7—The Greater The Use, The More Important Is Reliability

Fig. 8—Proper Care And Maintenance Can Double Machine Life

WORN-OUT MACHINERY

Finally, trade a machine when it is worn out or when it simply will not perform its job properly even with repairs. Here again, there is a tremendous difference in the total time from new to worn out. It depends on the kind of care the machine has had and how it is used. Proper daily care, periodic servicing and using care not to overload or abuse a machine can double or triple its life (Fig. 8).

CALCULATING MACHINE LIFE

By looking at the more typical or average situations, we could establish some useful guidelines for wear-out, least-cost or obsolescence life. Data in Table 1 is given for that purpose.

TABLE 1

AVERAGE MACHINE WEAR-OUT, LEAST-COST AND OBSOLESCENCE LIFE

	Wear-Out Life, Hours	Least-Cost Life, Hours	Obsolescence Life, Years
Tractors	10,000	8,500	10
Crawlers	16,000	16,000	20
Combines	3,000	2,000	8
Cotton pickers	2,000	2,000	8
Corn pickers	2,000	2,000	8
Mowers	1,000	750	8
Drills	1,000	1,000	8
Planters	1,000	1,000	8
Plows	2,000	2,000	8
Swathers	2,000	2,000	8
Hay equipment	2,000	2,000	8
Silage equipment	2,000	2,000	8
Tillage tools	2,000	2,000	8

Fig. 9—If A Tractor Or Machine Is Sized Properly For The Amount Of Annual Use It Is To Have, It Will Reach Its Trade Point Before Obsolescence

For those high annual use situations requiring equipment reliability, it might be feasible to trade at an earlier time than indicated in Table 1. For the best combination of least-cost and equipment reliability, the earliest trading time could be advanced to the point where total hours of use is one-half to three-fourths of those indicated for least-cost life in Table 1.

For example, information in Table 1 lists 8,500 hours as the least-cost life for tractors. To find the earliest feasible trade time, calculate both one-half and three-fourths of the least-cost life. Using a tractor as an example, one-half of the least-cost life (8,500 hours) is 4,250 hours. Three-fourths of the least-cost life is 6,375.

If certain machines, for example a tractor, have a high rate of usage throughout the year, this higher "priority of usage" and need for greater reliability may justify an earlier feasible trade time. In this case, the earlier trade time may be nearer to one-half of the least-cost point.

The obsolescence life of ten years for tractors and eight years for other machines, except crawlers, are arbitrary figures based on average annual usage.

If the tractor or machine is sized properly for its annual usage, it usually will reach its trade point, in terms of hours of usage, before it becomes obsolete (Fig. 9).

On new concepts of machines, use a shorter obsolescence life of about six years. In other words, don't rush out and buy a large model of a new machine concept on the basis that it must be owned for eight to ten years or more before its cost is justified.

With new machine concepts, you never really know how well it will work or whether it is the right size until you try it. It is better to plan to trade most "new concept" machines in six years or even less. In this way, you are not committed to a long ownership period of a machine that proves unfeasible for your situation.

WHEN TO REPAIR

Whether to trade or repair is a problem for machinery owners when they are limited on capital or want to cut costs without hurting production.

First of all, tractors and other machines seldom reach their point of minimum cost before the tenth year. There may be many reasons, including loss of reliability, that justify the trade before that time. If you are in a tight squeeze and really can't afford the trade, then here are some factors that you need to consider.

You can save expenses by rigidly following a good maintenance program.

Next avoid overloading and lugging down engines. Properly match machines and equipment (Chapter 5). These practices will help you avoid expensive repair costs to the engine and power train.

When To Repair And Keep On Using

1. If the machine or tractor has a good record of reliability.

2. If you have followed a good maintenance program and repairs have been only those expected (Chapter 8).

3. If there have been no problems with the engine and power train other than normal overhauls.

4. If equipment is adequate for your farming needs.

5. If the equipment in question is fairly simple like tillage tools, it is more economical to repair as long as the machine is functional and does not have a damaged frame, or bent axle.

TABLE 2

ANNUAL REPAIR COSTS FOR TRACTORS

	Repair Cost Per Year Per $1,000 List Price					
	ANNUAL HOURS OF USE					
YEAR	300	400	500	600	700	800
1	$3.29	$5.22	$7.46	$9.98	$12.78	$15.82
2	$6.69	$10.60	$15.15	$20.28	$25.96	$32.14
3	$9.12	$14.45	$20.64	$27.64	$35.37	$43.79
4	$11.17	$17.69	$25.28	$33.85	$43.31	$53.63
5	$12.99	$20.58	$29.41	$39.37	$50.38	$62.38
6	$14.65	$23.21	$33.18	$44.41	$56.84	$70.37
7	$16.20	$25.66	$36.68	$49.10	$62.83	$77.80
8	$17.65	$27.97	$39.97	$53.50	$68.47	$84.78
9	$19.03	$30.15	$43.09	$57.68	$73.81	$91.40
10	$20.34	$32.23	$46.06	$61.66	$78.91	$97.71
11	$21.60	$34.23	$48.91	$65.48	$83.80	$103.76
12	$22.81	$36.15	$51.66	$69.15	$88.50	$109.58
13	$23.98	$38.00	$54.31	$72.70	$93.04	$115.20

TABLE 3

ANNUAL REPAIR COSTS FOR COMBINES

	Repair Cost Per Year Per $1,000 List Price					
	ANNUAL HOURS OF USE					
YEAR	50	100	150	200	250	300
1	$0.44	$1.53	$3.18	$5.34	$7.98	$11.09
2	$1.09	$3.81	$7.90	$13.26	$19.82	$27.52
3	$1.65	$5.74	$11.91	$20.00	$29.88	$41.49
4	$2.16	$7.52	$15.60	$26.19	$39.13	$54.33
5	$2.64	$9.20	$19.08	$32.03	$47.86	$66.45
6	$3.10	$10.80	$22.41	$37.61	$56.20	$78.03
7	$3.55	$12.34	$25.61	$42.99	$64.24	$89.19
8	$3.98	$13.84	$28.72	$48.20	$72.03	$100.01
9	$4.39	$15.30	$31.75	$53.28	$79.62	$110.55
10	$4.80	$16.73	$34.70	$58.24	$87.03	$120.83
11	$5.20	$18.12	$37.59	$63.10	$94.29	$130.91
12	$5.60	$19.49	$40.43	$67.86	$101.40	$140.79
13	$5.98	$20.83	$43.22	$72.54	$108.40	$150.51

When To Trade

1. If the tractor or machine has had a major failure in the power train, such as the transmission, final drive, or ring gear.

2. If it breaks down frequently.

3. If you must make extensive repairs to a machine or tractor that is not properly suited to your needs.

4. If there is an opportunity to purchase or trade for a good used machine.

These guidelines may work for some situations. Let's examine some situations where a more complete cost analysis is needed.

Example: You have a 6-year old diesel tractor with 3,600 hours on it. You know that it will need extensive injection system repairs, an engine overhaul, and new tires. It cost $35,000 new. You can trade for a new one with the same horsepower for $18,000. What should you do?

Step 1. Assume the comparison for the next four years, which would take the present tractor to 10 years of age.

Step 2. Estimate the cost of repairs for your tractor for the next four years (Table 2).

The average repair costs for the $35,000 tractor for the next four years would be:

$35,000 divided by 1,000 = 35 cost units for Table 2

35 x ($49.10 + $53.50 + $57.68 + $61.66) = $7,768

The $7,768 figure represents an estimate for repairs for the old tractor for the next four years, and should cover all of the anticipated repairs listed earlier. In terms of cash flow and financial considerations, it will cost less than half as much to fix the old tractor than to trade for a new one. The new tractor would, however, start another ten years of serviceable life.

Look at another example:

Suppose that the same tractor needs a transmission overhaul that costs $4,000. Add this to the $7,768 of anticipated repairs over the next four years. This gives a total of $11,768 which is still well under the cost to trade.

However, the transmission failure may be a signal that other major failures of the power train might occur in the next four years. Each of these would be very expensive to make on an old tractor with little resale value. In this case you may save expenses if you sell the tractor and look for a reliable used one.

Table 3 gives the average annual repair costs for combines. Table 2 in Chapter 8 can be used to make estimates for other machines.

Example for a combine:

Let us suppose that you have an $80,000 list price combine that has been used eight years at 250 hours a year, What should you expect to pay for repairs over the next two years?

Look at Table 3. The anticipated repairs for the ninth year is $79.62 per $1,000 of list price and $87..03 for the tenth year.

80 cost units x ($79.62 + $87.03) = $13,332

It would cost a lot for you to trade, but you would have to consider the reliability of the combine after it is eight years old. Many combines have low annual hours of use. They must, however, be reliable and not be out of service during critical harvest periods.

SUMMARY

The most important factor in trading machinery for the best profits is to base trades on facts. The four important reasons for trading machinery discussed in this chapter are:

1) The average annual cost per unit is close to or has reached its minimum point.

2) The machine is obsolete.

3) The machine is unreliable.

4) The machine is worn out.

An increase in the size of an enterprise or wanting to take advantage of the first-year depreciation in investment credit are two other reasons to trade machinery that are discussed in previous chapters.

For most machines, the earliest feasible trade time occurs at approximately three-fourths of the least-cost life. Certain machines may have an earlier feasible trade time, depending on the rate of usage. When buying a machine that is a new concept, use a shorter obsolescence life of about six years.

CHAPTER QUIZ

1. List four main reasons why a machine should be traded.

2. How do you determine when a machine should be traded on the least-cost basis?

3. When is a machine no longer reliable?

4. What is the suggested obsolescence life for wheel tractors? Combines? Planters?

5. Your tractor is used 1,000 hours per year. When would you expect to trade it in? Explain why?

6. What are the reasons why you should repair or trade a used machine for a new one?

7. How much would the repair costs be for a tractor with a $60,000 list price for years 6 through 8 of ownership if it is used 500 hours a year?

8. What is the biggest problem in owning a combine that has a history of major repairs?

11

Considering Future Capacity Needs

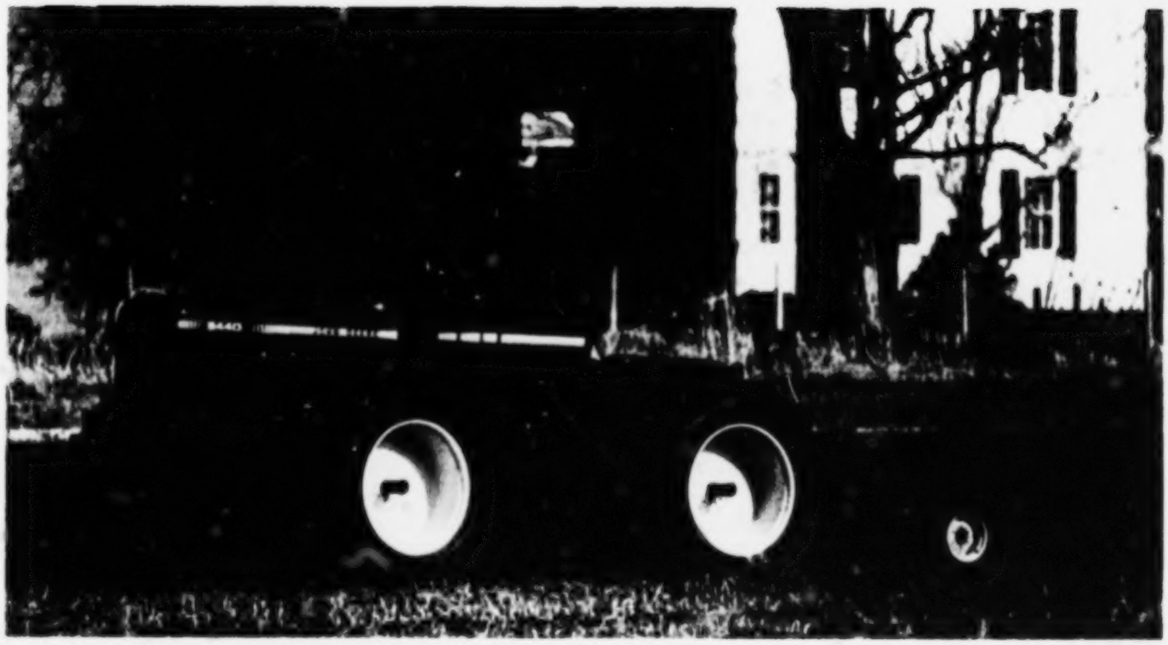


Fig. 1—Buy The Size That Will Get Important Jobs Done On Time

INTRODUCTION

An important aspect of buying a new machine or tractor is making the decision on what size of a machine is needed. Making this type of decision is the second step in developing machinery management skills.

It is better to buy the tractor or machine with adequate power or capacity, even if financing the purchase is necessary (Fig. 1). The amount of cash available at the time of purchase is not a really good basis for a decision.

If decisions are based on ready cash, the largest tractor manufactured could end up being used only 100 hours per year, or an undersized tractor may require too much time to complete a job. Other alternatives to ownership of machinery are available and will be covered in later chapters.

Another potential basis for machine selection might be to get equipment large enough to allow one person to do all of the work. This might be the best choice for smaller, less diversified operations.

Chances are, however, that managing larger, more diversified farming operations require more than one person to perform several ongoing jobs. The involvement of hired labor on expensive machinery usually means some type of supervision and the need for the manager to be available for on-the-spot decisions.

So the balance between labor and machine size is an important one. Certain types of agricultural enterprises may require a large amount of hired labor while labor requirements on other types may be reduced by larger machines. The important thing to remember is that labor-saving dollars may be eliminated or surpassed by extra-high fixed costs of extra-large machines. To help in making decisions when it comes to selection of machine or tractor size, we will discuss cost factors for two categories:

Fig. 2—Adequate Power Is Needed To Complete Key Operations, Such As Plowing, On Time

MARCH
S M T W T F S
1 2
3 4 5 6 7 8 9
10 11 12 13 14 15 16
17 18 19 20 21 22 23
24 25 26 27 28 29 30
31

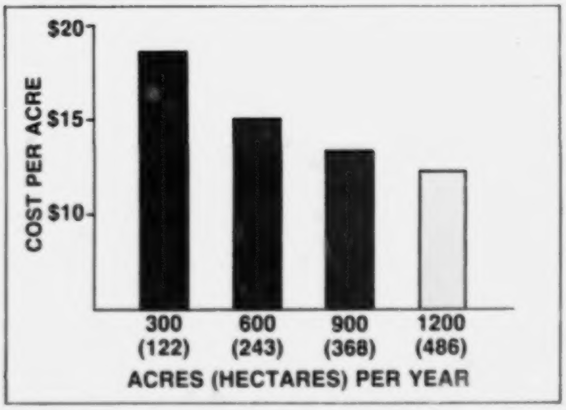


Fig. 3—Sufficient Annual Use Is Needed To Keep Costs Down

- **Selecting Tractor Size**
- **Selecting Machine Size**

An integral part of this chapter is selecting tractor size or machine size with regard to any future increase in the size of an agricultural operation.

Now, let's discuss tractor and machine size selection and the need to plan ahead.

SELECTING TRACTOR SIZE

A logical approach to deciding how large a tractor (or tractors) should be is to insure two things:

1. Provide for enough power to get all important field operations completed on time (Fig. 2).

2. Provide for sufficient annual use so costs will be minimized (Fig. 3).

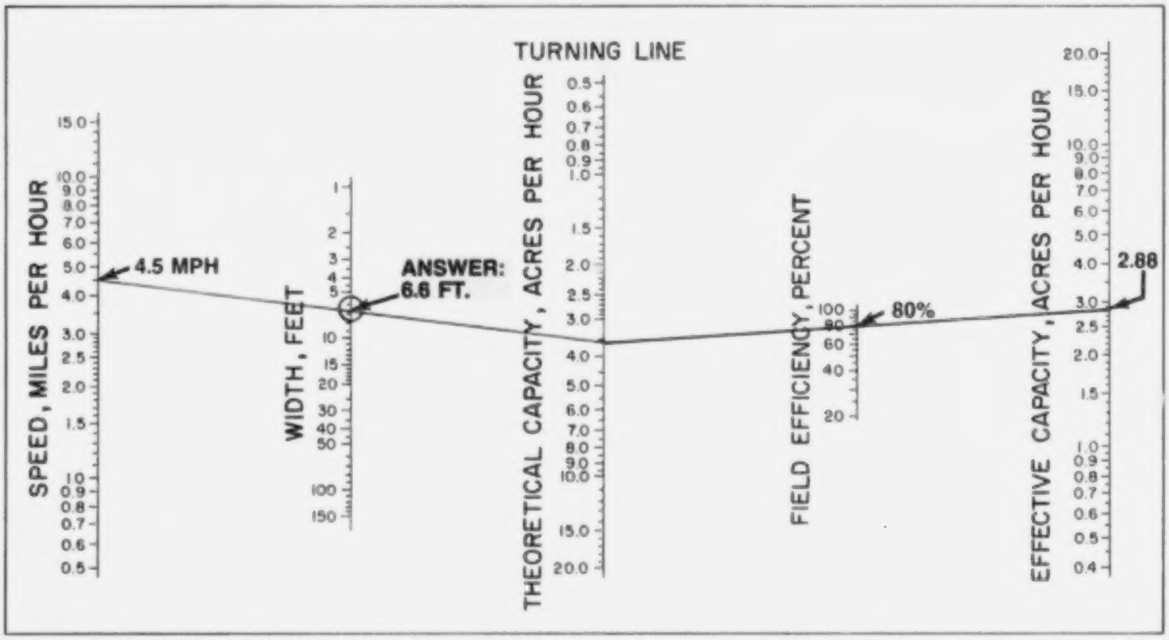
The first check point, then, is to list all field operations according to energy requirements and to estimate the total time available. For example, information in Table 2 of Chapter 4 shows plowing to have the highest energy requirement. In the following example, assume 400 acres (162 hectares) are to be plowed.

If using one tractor and plow, the average plowing capacity needed would be:

SAMPLE FALL PLOWING SCHEDULE

Operation	Calendar Periods	Average Working Days	Working Hours Per Day	Total Hours Available
Fall Plowing	Oct. 15-31	8.0	8.0	64.0
Fall Plowing	Nov. 1-15	6.5	7.5	48.8
Fall Plowing	Nov. 16-30	4.0	6.5	26.0
	TOTAL HOURS AVAILABLE = 138.8			

Fig. 4—The Nomograph in Chapter 4 Can Be Used To Determine The Plow Width Needed


TURNING LINE
SPEED, MILES PER HOUR
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.9
0.8
0.7
0.6
0.5
4.5 MPH
WIDTH, FEET
1
2
3
4
5
10
15
20
30
40
50
100
150
ANSWER:
6.6 FT.
THEORETICAL CAPACITY, ACRES PER HOUR
0.5
0.6
0.7
0.8
0.9
1.0
1.5
2.0
2.5
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
15.0
20.0
FIELD EFFICIENCY, PERCENT
100
80
60
40
20
80%
EFFECTIVE CAPACITY, ACRES PER HOUR
20.0
15.0
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.5
2.0
1.5
1.0
0.9
0.8
0.7
0.6
0.5
0.4
2.88

$$\frac{400\ \text{acres}}{138.8\ \text{hours}} = 2.88\ \text{acres per hour}$$

Ⓜ $$\frac{162\ \text{hectares}}{138.8\ \text{hours}} = 1.17\ \text{hectares per hour}$$

The plow size needed in the example can be determined from the nomograph in Chapter 4 (Fig. 4), or calculated as shown below, assuming:

- Speed = 4.5 miles per hour (7.2 km/h)
- Field Efficiency = 80 percent
- Draft = 800 pounds per foot

Using the formula for estimating width needed, estimate the plowing width needed in our example:

$$\textbf{Width} = \frac{\textbf{acres per hour} \times \textbf{8.25}}{\textbf{speed, mph} \times \textbf{field efficiency, percent}}$$

$$= \frac{2.88\ \text{acres per hour} \times 8.25}{4.5\ \text{mph} \times .80}$$

$$= 6.6\ \text{feet (80 inches)}$$

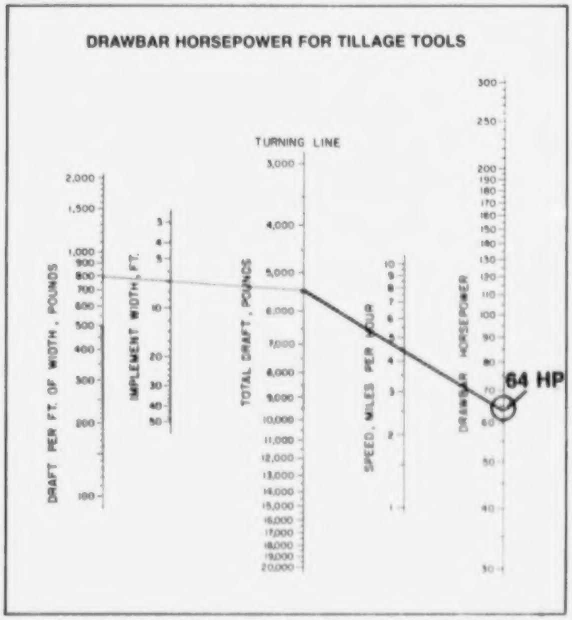
Ⓜ For metric formula required to determine width, see section on page 126.

Now that the required width is known, a 5-bottom, 16-inch plow or equivalent width would be needed.

Now let's see how much drawbar horsepower is needed to pull the same plow at 4.5 miles per hour with a draft of 800 pounds per foot. First, find the *total draft* of the plow:

6.6 feet × 800 pounds per foot = 5,280 pounds

Fig. 5—Horsepower Can Also Be Determined With The Nomograph From Figure 10, Chapter 5



Now find the drawbar horsepower required to pull the plow at 4.5 miles per hour:

$$\textbf{Drawbar hp} = \frac{\textbf{draft, pounds} \times \textbf{speed, mph}}{\textbf{375}}$$

$$= \frac{5280 \times 4.5}{375}$$

$$= 63.4\ \text{drawbar horsepower}$$

Ⓜ For metric formula used to determine drawbar kilowatts, see section on page 126.

For firm soil conditions, the actual drawbar power required will be approximately 67 percent (approximately 64 drawbar hp on the nomograph) of the maximum PTO-power rating of the tractor (Fig. 5). In this case, a tractor with 94.6 (63.4 drawbar hp/0.67) maximum PTO horsepower would meet the requirement.

CALCULATING RELATIVE COSTS

Sometimes the *relative cost* is an important factor. Suppose a buying decision is to be made on either a 100-horsepower tractor to be used 800 hours per year or a 125-horsepower tractor to be used 650 hours per year. Both tractors would accomplish the same amount of work.

If the 100-horsepower (75-kilowatt) tractor costs $35,000 and the 125-horsepower (93-kilowatt) tractor costs $42,000, which would be the most economical? Assign labor a cost of $5.00 per hour and diesel fuel a cost of $1.00 per gallon. Assume an 8-year ownership in both examples.

To better understand and compare the costs, let's discuss the costs for each tractor separately.

COSTS FOR 100-HORSEPOWER (75-kW) TRACTOR

The 100-horsepower (75-kW), diesel-engine tractor will be used 800 hours per year and costs $35,000 when new. Calculate each cost separately and then add them up for a total average cost.

Fixed Costs Plus Repairs

Use the chart in Figure 6 or the Appendix to determine the *constant* for fixed costs plus repairs for a 100-horsepower (75-kW) tractor. At 800 hours per year use, the cost would be $0.245 per hour per $1,000 cost of the tractor when new.

A $35,000 tractor would then have 35 cost units. To calculate the average fixed costs and repair costs, multiply the number of cost units by the constant:

35 units x $0.245 = $8.58 per hour for fixed costs plus repair costs.

Estimating fuel and lubricant costs is discussed in Chapter 7. Remember that the fuel consumption multiplier for

Useful life = 10,000 hours   Repair costs = $1,000 x .9 x .000631 X (% life)$^{1.6}$
Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

	Cost per hour per $1,000 of initial list price									
	(Age, Years)									
Hours of annual use	1	2	3	4	5	6	7	8	9	10
400	$1.176	$0.745	$0.598	$0.523	$0.475	$0.442	$0.418	$0.398	$0.382	$0.369
450	$1.047	$0.666	$0.536	$0.470	$0.429	$0.400	$0.379	$0.362	$0.349	$0.338
500	$0.945	$0.603	$0.487	$0.428	$0.392	$0.367	$0.349	$0.334	$0.323	$0.313
550	$0.861	$0.551	$0.447	$0.395	$0.362	$0.340	$0.324	$0.312	$0.302	$0.293
600	$0.792	$0.509	$0.414	$0.367	$0.338	$0.318	$0.304	$0.293	$0.285	$0.278
650	$0.733	$0.473	$0.386	$0.343	$0.317	$0.300	$0.287	$0.278	$0.271	$0.265
700	$0.683	$0.442	$0.363	$0.323	$0.300	$0.284	$0.273	$0.265	$0.259	$0.254
750	$0.639	$0.416	$0.342	$0.306	$0.285	$0.271	$0.262	$0.254	$0.249	$0.245
800	$0.601	$0.392	$0.325	$0.292	$0.272	$0.260	$0.251	$0.245	$0.241	$0.237
850	$0.568	$0.372	$0.309	$0.279	$0.261	$0.250	$0.243	$0.237	$0.234	$0.231
900	$0.538	$0.354	$0.296	$0.268	$0.252	$0.242	$0.235	$0.231	$0.228	$0.225
950	$0.511	$0.338	$0.284	$0.258	$0.243	$0.234	$0.229	$0.225	$0.222	$0.221
1,000	$0.488	$0.324	$0.273	$0.249	$0.236	$0.228	$0.223	$0.220	$0.218	$0.217
1,050	$0.466	$0.311	$0.263	$0.241	$0.229	$0.222	$0.218	$0.215	$0.214	*
1,100	$0.447	$0.300	$0.255	$0.234	$0.223	$0.217	$0.214	$0.212	$0.211	*
1,150	$0.429	$0.289	$0.247	$0.228	$0.218	$0.213	$0.210	$0.208	*	*
1,200	$0.413	$0.280	$0.240	$0.222	$0.213	$0.209	$0.206	$0.205	*	*

*** No cost shown since total use is greater than expected life of the machine.**

Fig. 6 — At 800 Hours Per Year, Fixed Costs Plus Repair Costs Equal $0.245 Per Hour Per $1,000 Of Initial Cost

diesel-engine tractors is 0.044. The equivalent multiplier when metric figures are used is .223.

First, calculate the fuel cost:

100 hp x 0.044 x $1.00 per gallon = $4.40 per hour

Ⓜ 75 kW x 0.223 x $0.264 per liter = $4.42 per hour
Note: The metric example gives a slightly different answer due to rounding of numbers.

Next, add 10 percent of the fuel cost as the lubricant cost:

$4.40 + (.10 x $4.40) = $4.84 per hour

So we have a total of $4.84 per hour as the average cost for fuel and lubricants for the 100-horsepower (75-kW) tractor. A nomograph may also be used to determine the average fuel and lubricant cost.

Fixed costs plus repairs	=$ 8.58 per hour
Fuel and lubricant costs	=$ 4.84 per hour
Labor	=$ 5.00 per hour
TOTAL AVERAGE COSTS	=$18.42

COSTS FOR THE 125-HORSEPOWER (93-kW) TRACTOR

The 125-horsepower (93-kW) $42,000 diesel-engine tractor will be used 650 hours per year over an 8-year period. Once again, let's calculate each cost involved.

Fixed Costs Plus Repairs

The constant for fixed costs plus repairs for tractors is $0.278 per hour per $1,000 of new cost (Fig. 6). Because the tractor costs $42,000 when new, we have 42 cost units. Now, calculate the fixed cost plus repair costs for this tractor:

42 units x $0.278 = $11.68 per hour

Fuel And Lubricant Costs

Fuel and lubricant costs are calculated as in the previous example only this time for a 125-horsepower (93-kW), diesel-engine tractor (Fig. 7):

125 hp x 0.044 x $1.00 = $5.50

Ⓜ 93 x 0.223 x $0.264 = $5.48

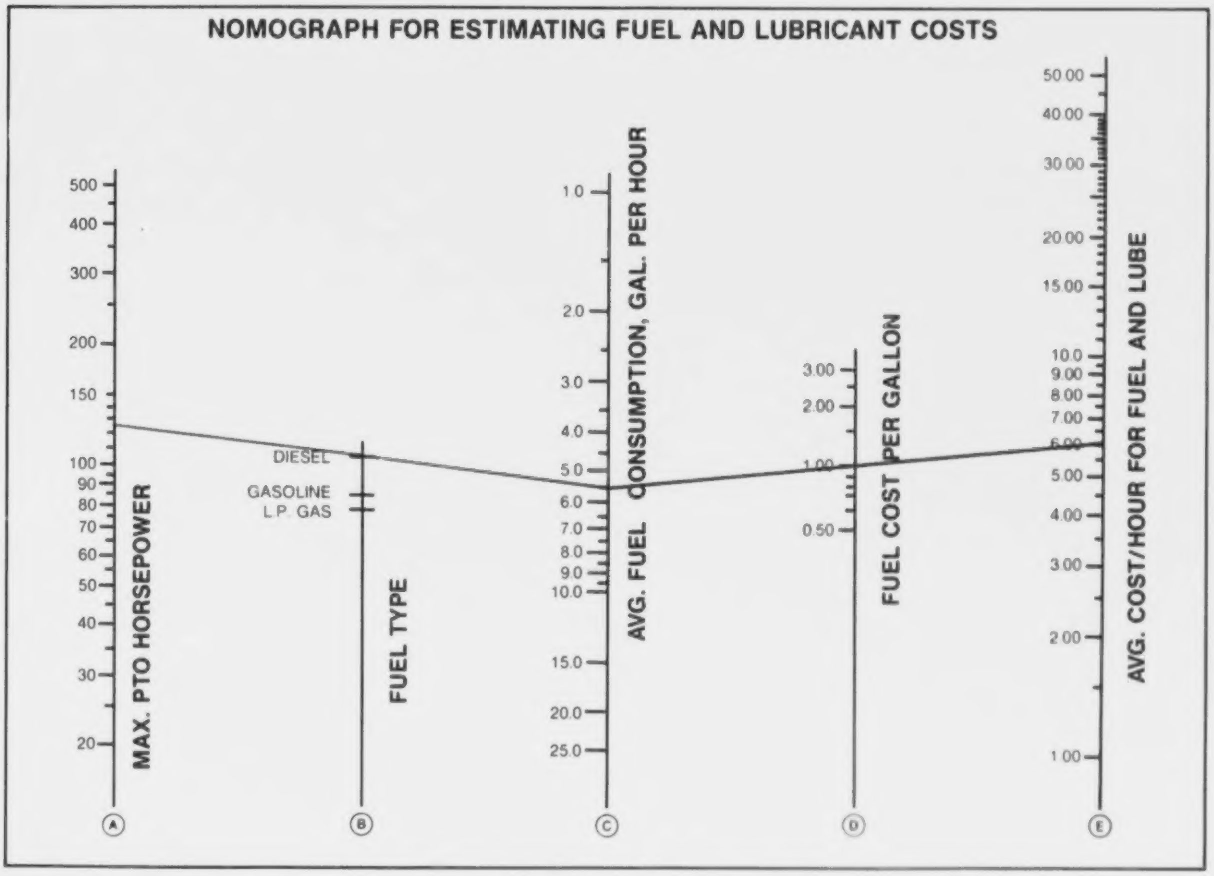


Fig. 7—The Alignment Chart In Figure 11, Chapter 7, Can Also Be Used To Find Fuel and Lubricant Costs

$5.50 + (.10 x $5.50) = $6.05 fuel and lubricant cost per hour

Total cost per hour = $11.68 + $6.05 + $5.00
= $22.73 per hour

Total Average Annual Costs

Next, use the total cost per hour to estimate the total annual cost for each tractor.

The 100-horsepower (75-kW) tractor is used 800 hours per year and has a total cost per hour of $18.42:

800 hours x $18.42 per hour = $14,736

The 125-horsepower (93-kW) tractor is used 650 hours per year and has a total cost per hour of $22.73:

650 hours x $22.73 per hour = $14,775

By comparison we see that the two tractors have almost the same annual costs, including labor ($14,736 per year for the 100 horsepower tractor and $14,775 for the 125 horsepower tractor).

100-hp (75-kW) tractor = $13.42 per hour x 800 hours per year

= $10,736 per year

125-hp (93-kW) tractor = $17.73 per hour x 650 hours per year

= $11,525 per year

Without labor, the *added* annual cost of using the 125-horsepower (93-kW) tractor is $789 per year.

This is a good example of the advantage of properly sizing the tractor for minimum costs, when each size of tractor is to accomplish the same amount of work.

Average costs for both the tractors (including labor) are shown in Figure 8.

To summarize:

1. Enough power is needed to get important jobs done *within* the allotted time.

2. Keep costs down and do not buy *excessively* large tractors.

3. Determine the value of the time saved by using the larger tractor.

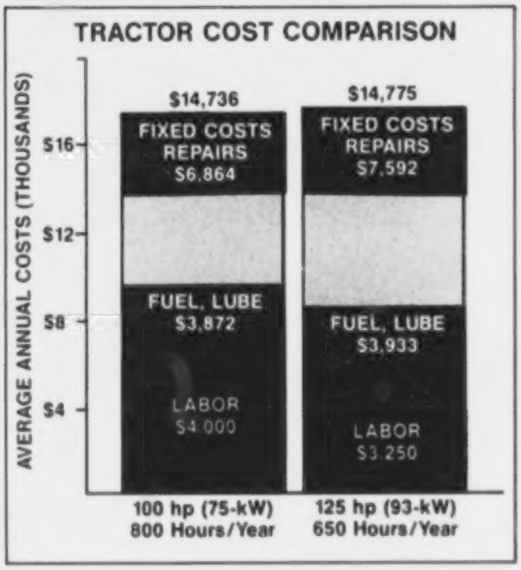


Fig. 8—Comparison Of Costs For Two Sizes Of Tractors

ALLOWING FOR EXPANSION

When buying a tractor, there is another important factor to consider. Plan ahead and consider the possibility of the size of the operation increasing in the future. It is much better to buy a larger tractor than needed when trading than to have to trade up to a larger tractor in two or three years (Fig. 9).

The process for making this kind of mathematical comparison is complicated. The example is kept simple, but the principle is important to understand. The assumptions for our example are as follows:

- Total time period is eight years
- Diesel fuel is $1.00 per gallon ($0.26 per liter)
- Labor is $5.00 per hour
- Number of acres involved will increase after two years

The comparisons for the following example are shown in Figure 10. Bar A in the graph represents the costs for Situation A, and bar B represents the costs for Situation B.

Situation A

Situation A consists of a 100-horsepower (75-kW), diesel-engine tractor with a new cost of $35,000. It is used 600 hours per year for two years and then traded for a 125-horsepower (93-kW) tractor because of the increase in acreage. The new tractor costs $42,000 and is used 600 hours per year for the next six years.

Fig. 9—It Is Better To Buy A Larger Tractor When Trading Than To Have To Trade For A Larger One In Two Or Three Years

Situation B

Situation B consists of buying a 125-horsepower (93-kW) tractor initially with a new cost of $42,000. It is used 480 hours per year for two years, then used 600 hours per year because of the increase in acreage.

The costs for both situation A and situation B are shown in Figure 10. Notice that $12,437 is saved over a period of eight years by buying a larger tractor initially. This example points out one good way to save money with machinery management decisions by taking longer-range plans into consideration.

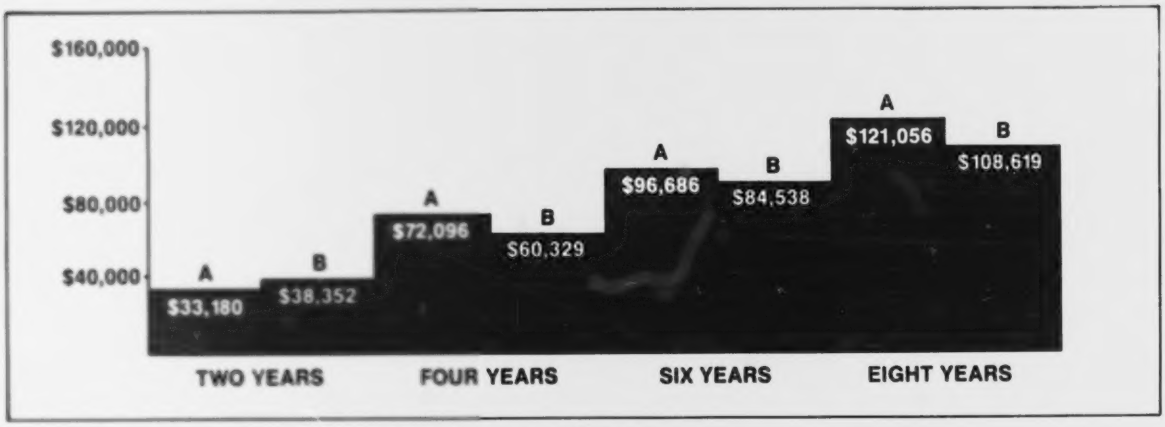


Fig. 10 — Buying The Proper Size Tractor Saved $12,437 over An Eight Year Period

SELECTING MACHINE SIZE

In buying a machine for farming, there are three important considerations:

1. Selecting proper size for the power unit.

2. Getting sufficient capacity to get needed work done within the allotted time period.

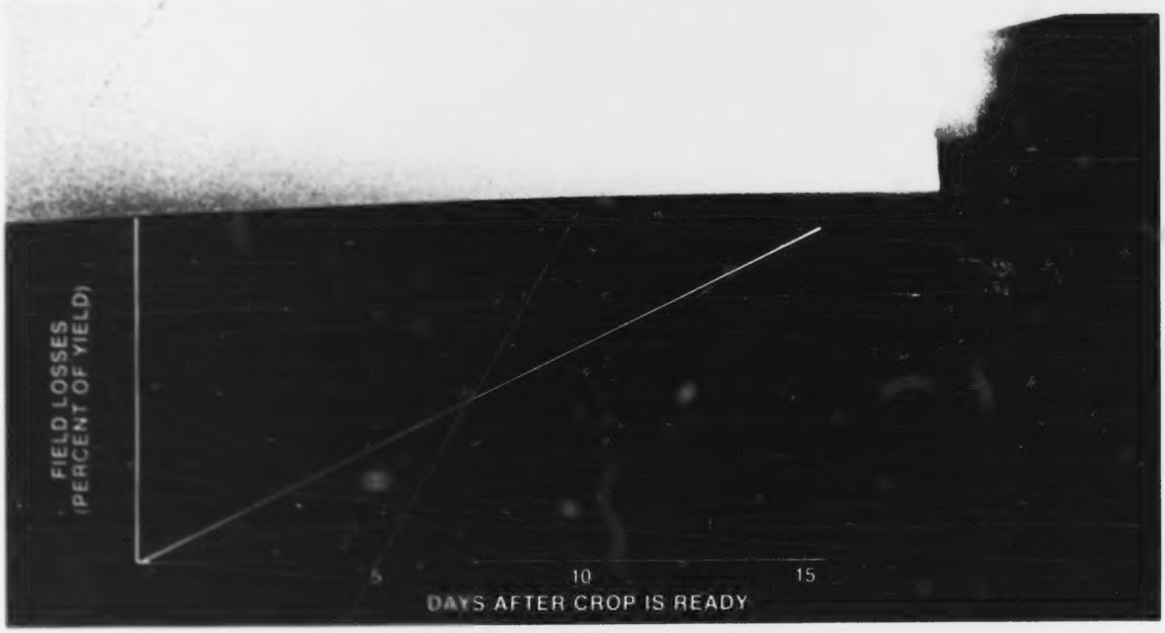
3. Making a decision which results in maximum net profit.

Matching the machine to a power unit has been discussed earlier in Chapter 4 and can be reviewed there. Determining capacity needed to get over a given number of acres within an allotted time period was also covered in Chapter 4. Two other important considerations are:

- **Timeliness**
- **Alternative costs**

Let's discuss these two factors further.

Fig. 11—Once A Crop Is Ready For Harvest, Field Losses Increase After That Point



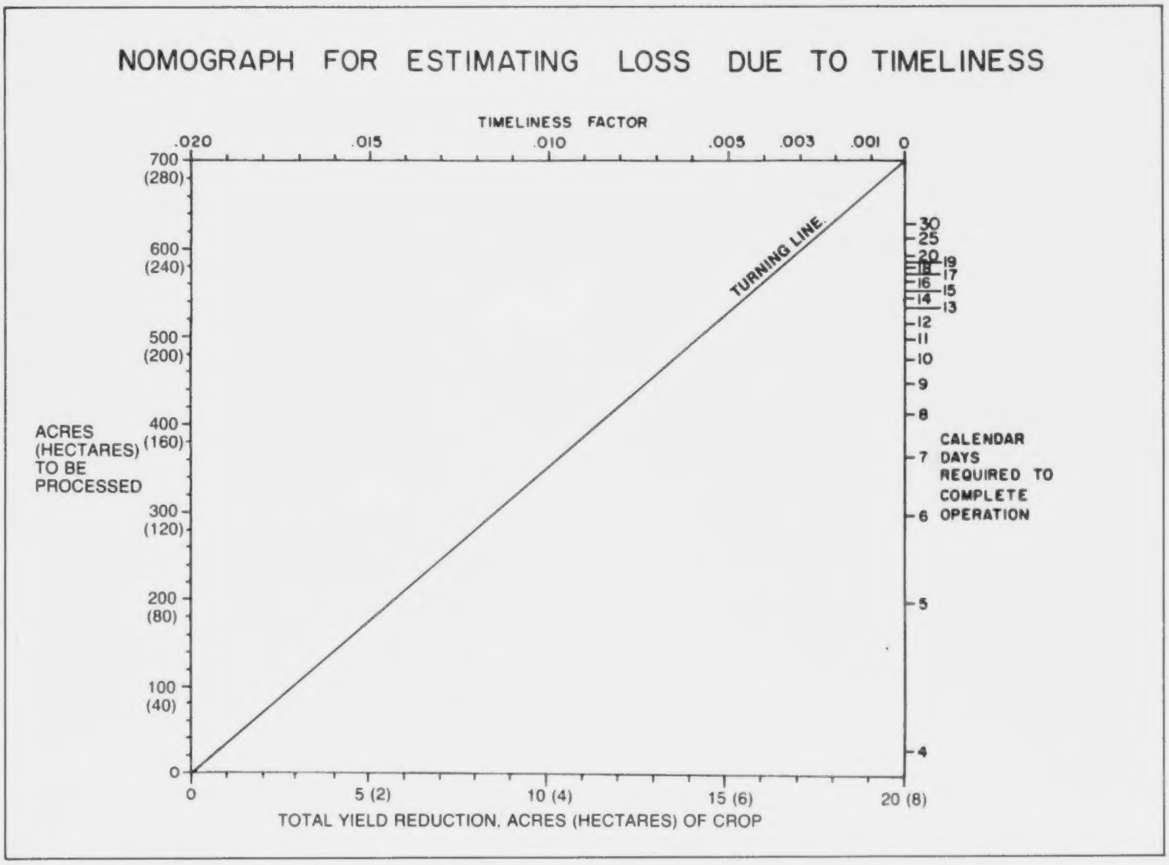


Fig. 12—Use This Nomograph To Estimate Timeliness Losses

TIMELINESS

In sizing machines, always consider the importance of *timeliness* (Fig. 11). Unfortunately there is no easy way to calculate the answer for a timeliness factor.

TABLE 1

ESTIMATING TIMELINESS LOSSES

TIMELINESS IMPORTANCE	TIMELINESS LOSS, PERCENT LOST PER DAY OF DELAY	TIMELINESS FACTOR
Very high	1.0%	.010
High	0.8%	.008
Medium	0.6%	.006
Low	0.4%	.004
Very Low	0.2%	.002

The information in Table 1 is one way to estimate timeliness penalties in a machinery selection problem. Remember that staying ahead in important timeliness situations, such as planting corn or combining soybeans, means more "bushels in the bin" and a better resulting profit.

These figures have been developed as a result of several research reports comparing the total crop produced and harvested where different time periods are required.

Let's look at how the percentage factors in Table 1 work.

If using a medium timeliness factor of 0.6 percent, what is the amount of timeliness penalty for each day that 100 acres (40 hectares) of cotton go unplanted? To estimate the timeliness loss, simply multiply the timeliness value (Table 2) by the number of acres times the number of days delayed:

100 acres (40 ha) × 0.006 × 1 day = 0.6 acres (0.25 ha) lost

These timeliness values assume reduction in yield for a delay following the most favorable time period for the operation. To find which timeliness values

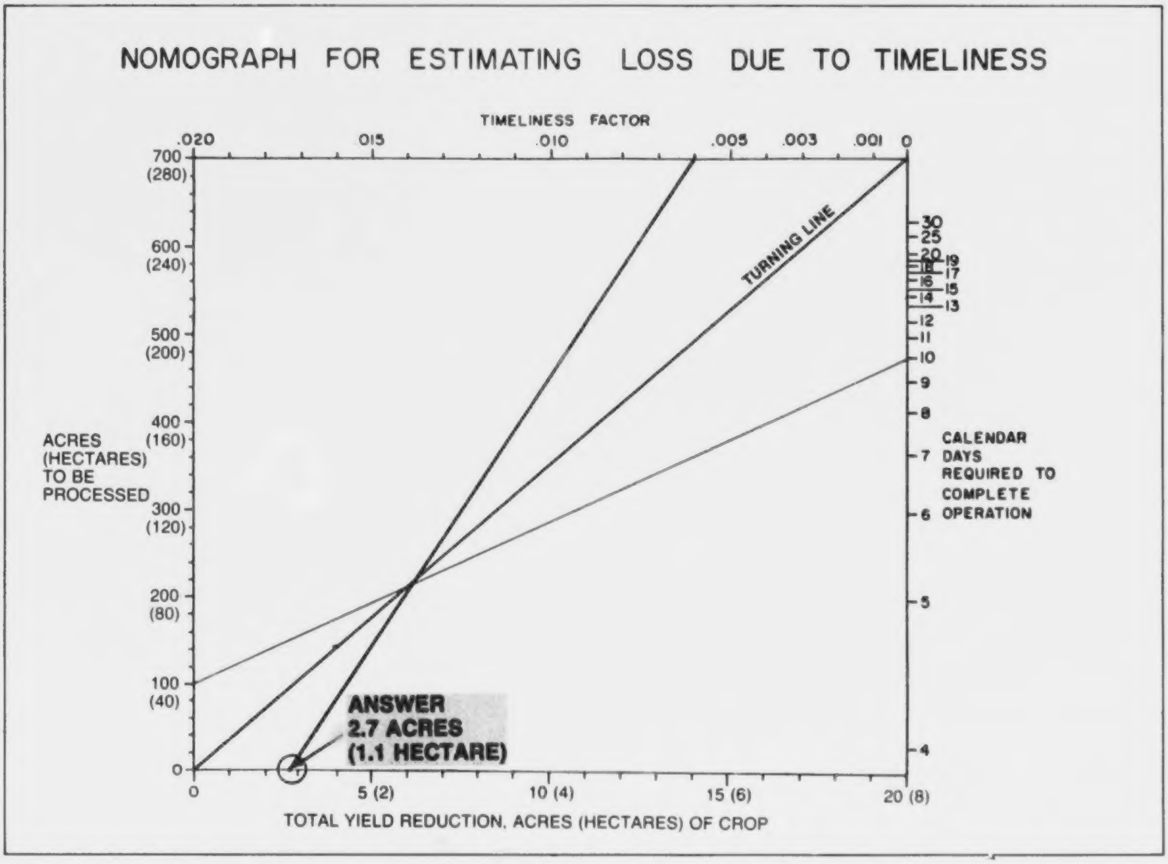


Fig. 13—If It Takes 10 Calendar Days To Plant 100 Acres (40 Hectares) With A Timeliness Value Of 0.6 Percent Per Day, The Equivalent Of 2.7 Acres (1.1 Hectares) Would Be Lost Due To Timeliness Loss

to use, information is given in Table 2 for use only as a guide. It will not provide an exact answer for all situations.

A nomograph that can be used as a guide in estimating the timeliness penalty for a specific operation is shown in Figure 12.

In using this nomograph, remember it is only a rough guide to determine a timeliness penalty. Here's how it can be used.

PROBLEM: What is the equivalent loss in acres for taking 10 calendar days to plant 100 acres (40 hectares) if the timeliness value is 0.6 percent per day?

SOLUTION: Using the nomograph, draw two lines to solve this problem (Fig. 13). Draw the first line between the given data points from top to bottom or from side to side, depending on what data is available. In this case, the opposing data points given

TABLE 2
TIMELINESS VALUES GUIDE

Timeliness Importance	Value, Percent Per Day	Operation
Very high	1.0%	Corn planting Sowing oats Harvesting soybeans Hay operations
High	0.8%	Planting soybeans Planting peanuts Harvesting peanuts
Medium	0.6%	Planting cotton Harvesting oats
Low	0.4%	Harvesting wheat Harvesting barley Harvesting corn Harvesting cotton

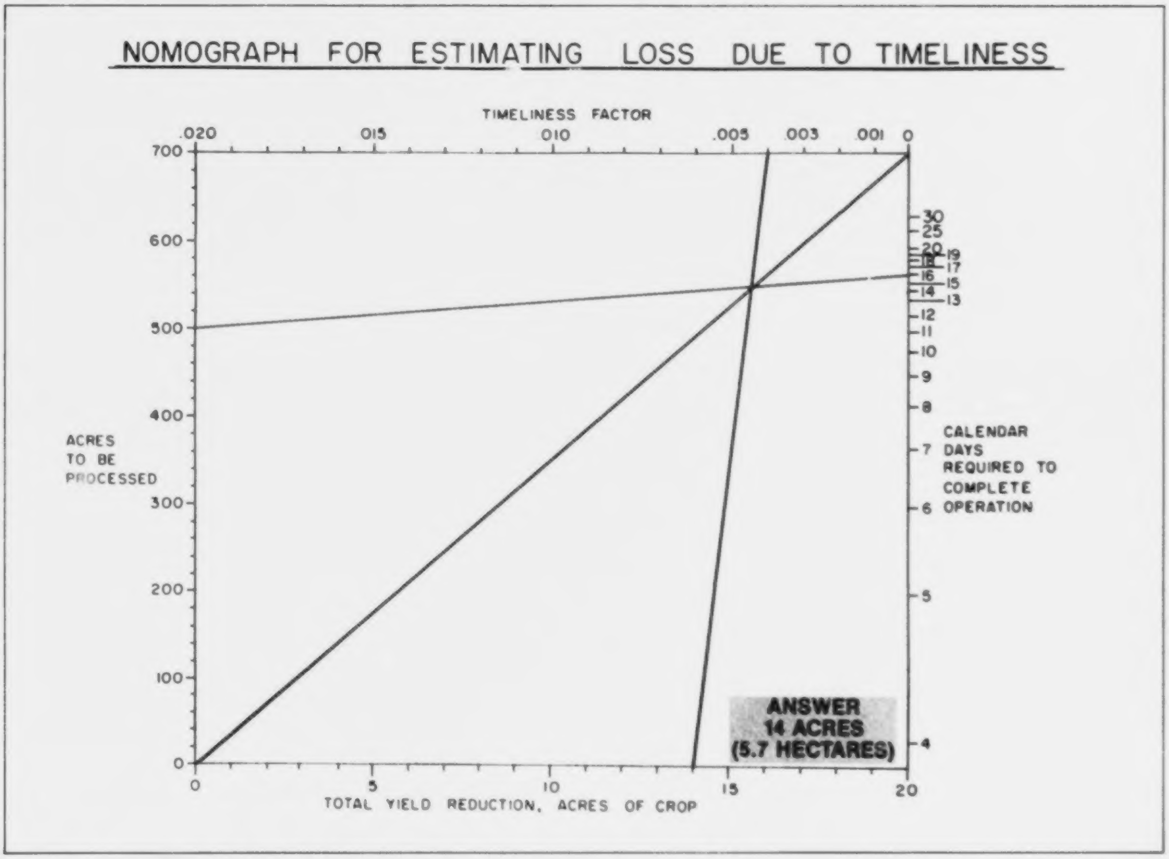


Fig. 14 — The Equivalent Loss For Taking 16 Days To Combine 500 Acres (200 Hectares) With A Timeliness Value of 0.4 Percent Per Day Is 14 Acres (5.7 Hectares)

are 100 acres (40 hectares) and 10 days so a line is drawn between those two points (orange line).

Draw the second line (brown) from the third data point available (.006 or 0.6 percent) and intersect the point where the first line intersects the turning line. The second line will then intersect the opposite side to provide the answer of 2.7 acres (1.1 hectare).

Now let's try a problem where we want to find what the additional penalty in crop loss would be for taking 16 calendar days to harvest 500 acres (200 hectares) of wheat instead of finishing harvest in 10 calendar days.

First of all, information in Table 2 indicates a timeliness value of 0.4 percent (0.004 on the graph) per day for harvesting wheat. In using the nomograph, two straight lines are drawn, as indicated in both Figure 14 and 15.

The answer for the first situation, where 16 days for harvest is needed, is the equivalent of 14 acres (5.7 hectares) of wheat being lost (fig. 14). For the second situation, where 10 days are needed for harvest, an equivalent crop value of 8.5 acres (3.4 hectares) would be lost — 5.5 acres (2.2 hectares) less than for requiring 16 days for harvest (Fig. 15).

This technique computes an equivalent amount of crop value lost due to the total time required for harvest. Most research will indicate field losses increase for each day of delay after a crop has reached an optimum moisture level for harvest.

The same situation for harvesting corn with combines is shown in Figure 16.

Above 26 percent grain moisture, the corn may be standing perfectly but the higher moisture grain doesn't shell off the cob cleanly. The heavy green fodder also makes separation more difficult.

At the lower grain moisture, particularly when less than 21 percent moisture, the cornstalks may start lodging. The corn may be shelled at the snapping units also, causing field losses to increase.

The same principle applies to almost any crop. Field losses increase after a certain stage of crop maturity. Timeliness factors allow an approximation of

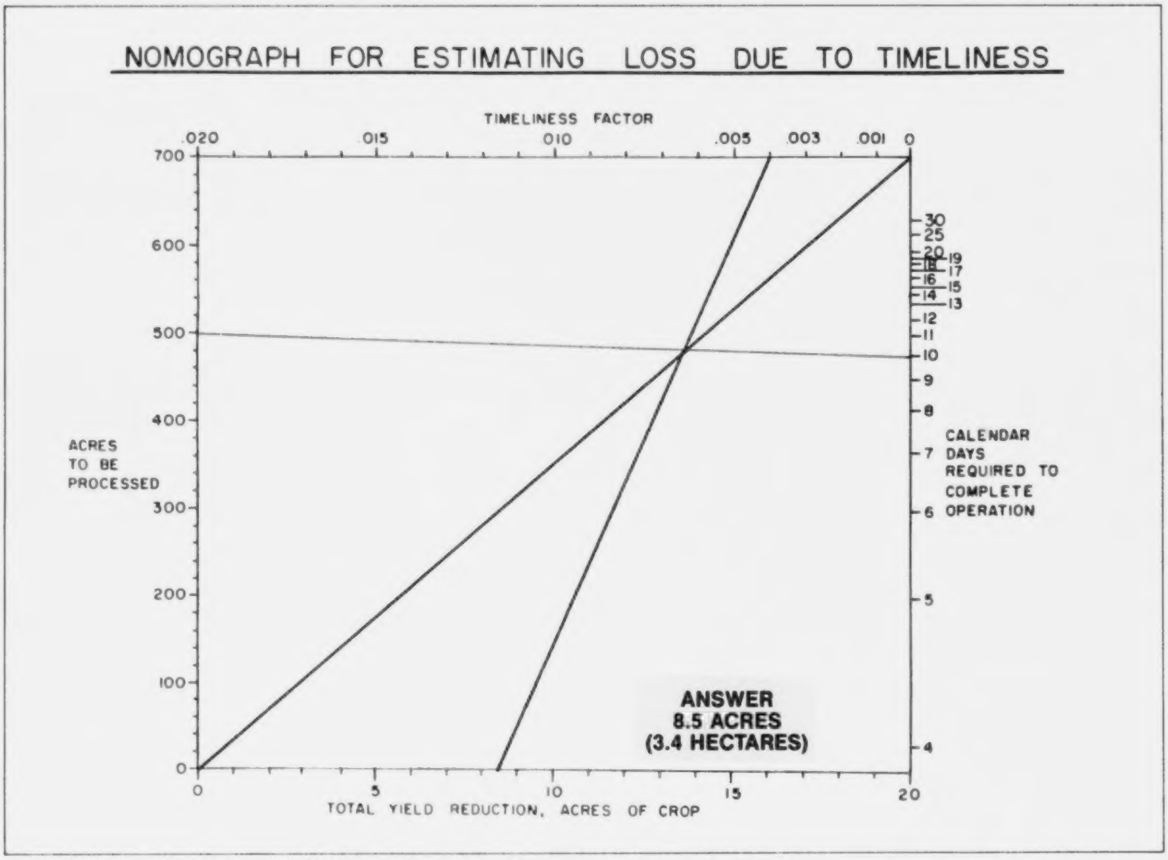


Fig. 15 — The Equivalent Loss For Taking 10 Days To Combine 500 Acres (200 Hectares) With A Timeliness Value Of 0.4 Percent Is 8.5 Acres

the value of this kind of a penalty. The higher the value of the crop on a per-acre basis, the more significant is the effect of a timeliness loss.

Putting A Value On Timeliness Losses

Let's take our previous example of combining wheat one step further and learn how to put a meaningful value on timeliness losses. See page 126 for these formulas when using metric equivalents.

PROBLEM: The wheat yield would have been 30 bushels per acre if harvested on the first optimum moisture and yield day. It is sold at the elevator without a penalty at a value of $3.00 per bushel. What would it cost in dollars to take the extra 6 days to harvest the wheat?

SOLUTION: When it took 16 days to complete the harvest, the equivalent loss was determined to be 14 acres. For a ten-day harvest, the equivalent loss was 8.5 acres. So in the first case, the equivalent of 486 acres (500-14) was actually harvested. Therefore:

486 acres x 30 bushels per acre = 14,580 bushels harvested

But when harvest was finished in ten days, the equivalent of 491.5 acres (500-8.5) was harvested:

491.5 acres x 30 bushels per acre = 14,745 bushels harvested

If wheat is selling for $3.00 per bushel, the difference due to timeliness factors is $495 (165 bushels x $3.00). An extra annual cost of $495 is justified to complete the harvest in ten days instead of 16 days (Fig. 17).

CALCULATING ALTERNATIVE COSTS

Once the technique of estimating timeliness values is mastered, one additional step is possible. A decision on how much equipment or what alternative to use can now be made.

To decide on what size of equipment to buy, make an accurate cost estimate for each alternative, then cor-

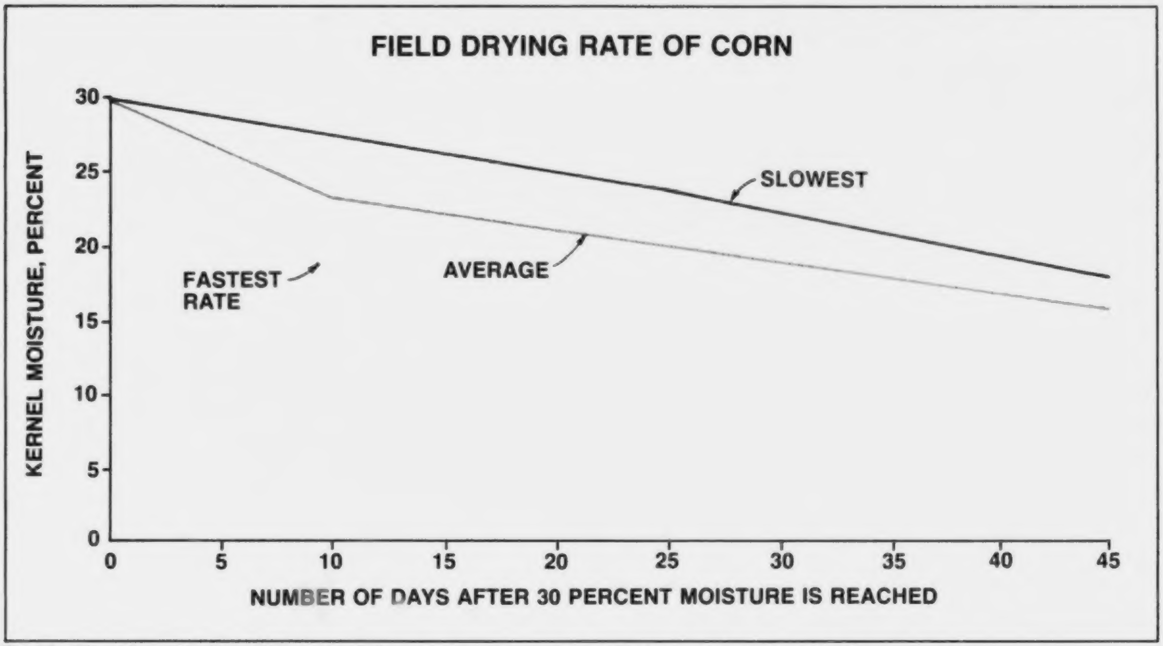


Fig. 16—When Harvesting Corn, There Is An Optimum Moisture Content For Each Variety And Each Combine Setting That Gives The Lowest Field Losses. This Is Why Timeliness Losses Increase Daily After The Best Time For Harvest Passes

rect the cost for the timeliness factor. As a shortcut in estimating costs, use fixed costs and labor costs only. The costs for repairs, fuel and lubricants will be fairly constant on a per-acre basis.

Going back to our previous example, suppose the 500 acres (200 hectares) of wheat can be cut in 16 days with a $50,000 combine, but the extra capacity needed to finish in 10 days would mean having a $64,000 combine. The fixed-cost percentage is 14.49 percent for an 8-year ownership period and 13.04 percent for 10-year ownership (Table 6, Chapter 6).

Fig. 17 — You Could Justify $495 More A Year In Harvest Costs To Finish In Ten Days Instead of 16 Days

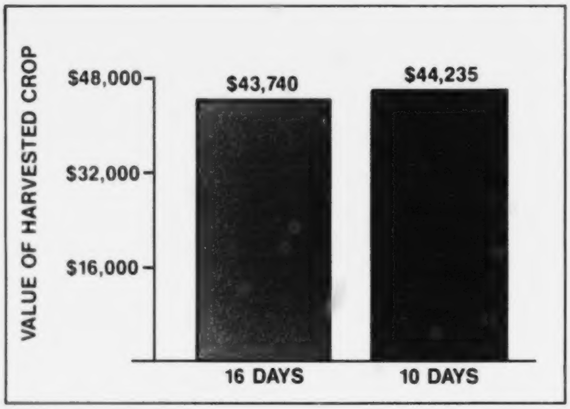


Figure the smaller combine's capacity at 5 acres (2 hectares) per hour, the larger combine's capabity at 8 acres (3.25 hectares) per hour, and labor at $6.00 per hour. Because fuel, lubricant and repair costs would be the same per area harvested for both combines, these costs are not included in the following example:

COMBINE COSTS

Initial Cost	Average Annual Fixed Cost	Annual Labor Cost	Total Crop Value*	Net Crop Value**
$64,000	$8,346	$375	$44,235	$35,514
$50,000	$7,245	$600	$43,740	$35,895

*Total crop value including timeliness penalty
**Total crop value less labor and machinery costs

In this situation, the previously calculated difference of $495 was not enough to offset the added costs of the larger combine. The final decision on which combine to purchase would depend on the manager's situation. The crop value difference of only $381 is not very much when you consider the weather risk involved with wheat harvest, particularly if wheat sells for $4.00 a bushel.

METRIC EQUIVALENTS

SELECTING TRACTOR SIZE

The following formulas relate to information given on page 116 in U.S.A. customary measurements.

$$\textbf{Width, meters} = \frac{\textbf{hectares per hour} \times \textbf{10}}{\textbf{speed, km/h} \times \textbf{field efficiency, \%}}$$

Speed — 7.2 km/h

Capacity — 1.2 ha/hr

Field efficiency — 80 percent

$$\text{Width} = \frac{1.2 \times 10}{7.2 \times 0.8} = 2.08 \text{ meters}$$

$$\textbf{Drawbar power, kW} = \frac{\textbf{draft, kilogram} \times \textbf{speed, km/h}}{\textbf{367}}$$

Draft — 2400 kg

Speed — 7.2 km/h

$$\text{Drawbar kW} = \frac{2400 \times 7.2}{367} = 47 \text{ kW}$$

PUTTING A VALUE ON TIMELINESS

Metric equivalent to problem on page 124.

What would it cost in dollars to take the extra six days to harvest the wheat?

Wheat yield — 2,020 kilograms per hectare

Price (without penalty) — $0.1125 per kilogram

SOLUTION: When it took 16 days to complete the harvest, the equivalent loss was determined to be 5.7 hectares. For a 10-day harvest, the equivalent loss was 3.4 hectares. So in the first case, the 194.3 hectares (200-5.7) was actually harvested. Therefore:

194.7 hectares x 2,020 kilograms per hectare = 393,294 kilograms harvested. But when harvest was finished in 10 days, 196.6 hectares (200-3.4) was harvested:

196.6 hectares x 2,020 kilograms per hectare = 397,132 kilograms harvested.

If wheat is selling at $0.1125 per kilogram, the difference between harvest timeliness factors in this case is $432 (3,838 x $0.1125). An extra annual cost up to $432 is justifiable to complete the harvest in 10 days instead of 16.

Note: The metric example differs slightly from the previous example due to rounding the metric units.

SUMMARY

Planning tractor and machine purchases wisely is an important part of machinery management. Buying machines should also include sizing the machine for any future increases in the number of acres operated. Always buy the tractor or machine that is large enough to get the job done on time, even if financing is necessary.

Two important considerations to keep in mind when buying a tractor are:

1. Provide for enough power to get all important field operations done on time.
2. Provide for sufficient annual use so costs will be minimized.

Three factors to consider when buying a machine are:

1. Selecting proper size for the power unit
2. Getting sufficient capacity to get needed work done within the allotted time period.
3. Making a decision which results in maximum net profit

CHAPTER QUIZ

1. What are the three important factors to consider when deciding how large a machine to buy?

2. How much combining capacity is needed to combine 400 acres in 12 calendar days if averaging six hours in the field per calendar day?

3. Which costs more per year to operate? How much more?

a) A $30,000, 75-horsepower (56-kW) tractor used 600 hours per year?

b) A $35,000, 100-horsepower (75-kW) tractor used 450 hours per year?

Assume both are owned 8 years, diesel fuel costs $1.00 per gallon (0.26 per liter) and labor is $4.00 per hour.

4. How would the answer for Problem 3 change if labor costs $6.00 per hour?

5. If it takes 15 days to plant 600 acres (240 hectares) of corn, what would be the equivalent of timeliness loss?

6. If you plant the same 600 acres (240 hectares) discussed in Problem 5 in 7 days and corn is $2.50 per bushel bushel, how much additional annual cost for the higher planting capacity could be justified? Assume the yield to be 100 bushels per acre (6275 kg/ha) if planted on the best day.

12

Calculating Custom Work Costs

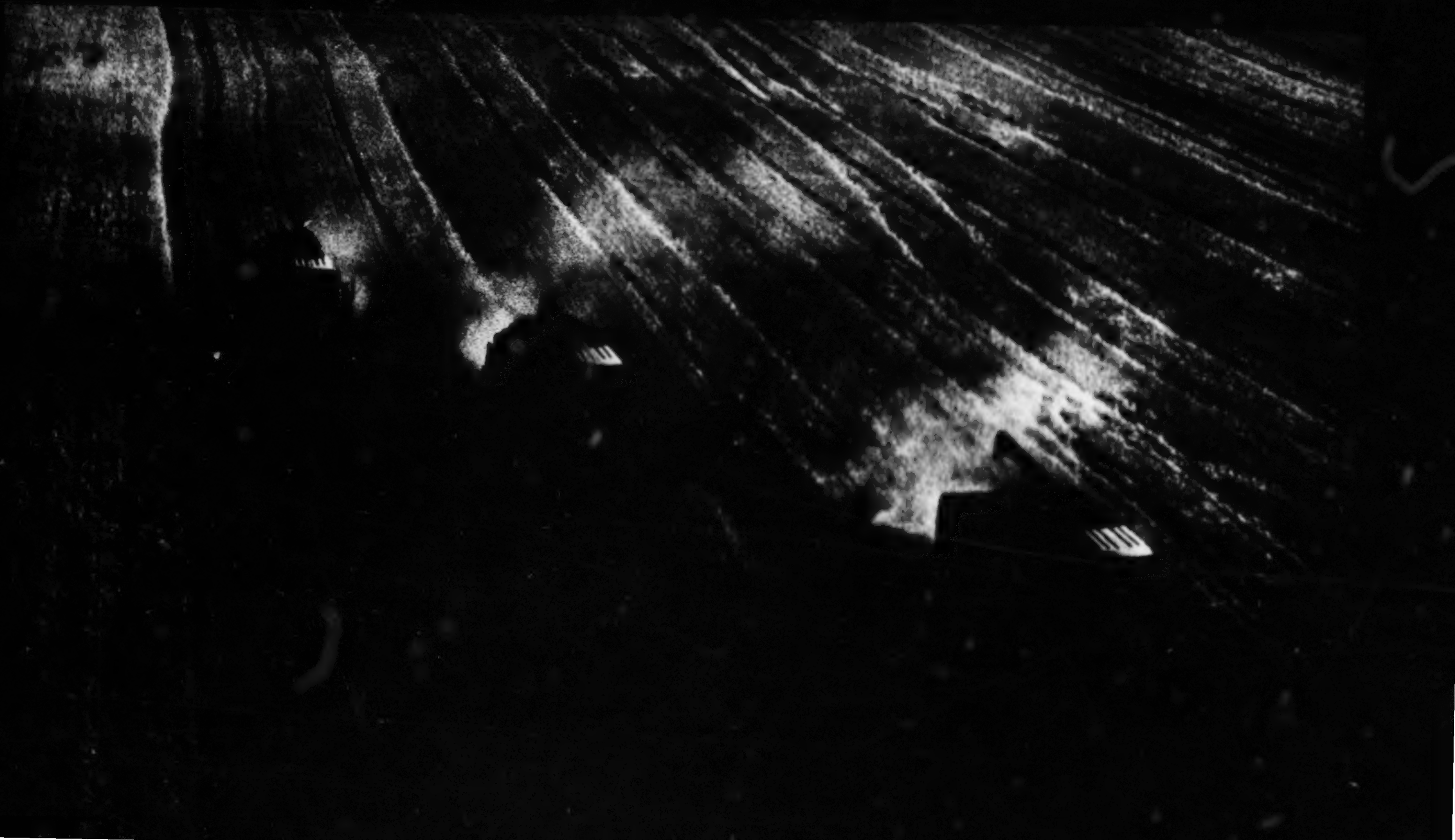


Fig. 1—For Some Operations, It May Be Better To Use A Custom Operator

INTRODUCTION

Hiring custom operators is one important alternative to owning machinery. In some cases, using custom operators provides faster completion of work, provides the least-cost method, and does not require the capital needed for owning a machine (Fig. 1). In other cases, doing additional custom work can help a farm operator justify ownership costs.

But when considering hiring a custom operator, do not forget timeliness considerations. Waiting on a custom operator to arrive is expensive in terms of timeliness if it means not getting crops planted or harvested at the optimum time. Always consider timeliness in making a decision to use either a custom operator or an alternative method.

DETERMINING AND COMPARING COSTS

Determining *when* to use a custom operator is one of the most important decisions made in machinery management (Fig. 2). There is a rather simple formula for calculating the break-even point for owning machinery versus custom work.

The formula for calculating the area harvested per year (acres or hectares) to justify machine ownership is:

$$\frac{\textbf{Average Annual Fixed Costs}}{\textbf{Custom Rate — Operating Costs Per Area}}$$

As explained in Chapter 6, certain fixed costs are incurred just by owning a machine, regardless of annual use. These costs must justify ownership on the basis of annual use (Fig. 3).

Once the machine is purchased, the only additional costs are fuel, oil, lubricants, labor and repairs. These costs, by themselves, are considerably lower than custom rates.

Thus, each acre or hectare of annual use will provide additional money to pay off the ownership costs (fixed costs). Let's illustrate this method with a simplified example.

Suppose it costs $2,500 a year just to own a pull-type windrower (depreciation, taxes, shelter, insurance, interest). The custom operator charges $10.75 an acre. Figure

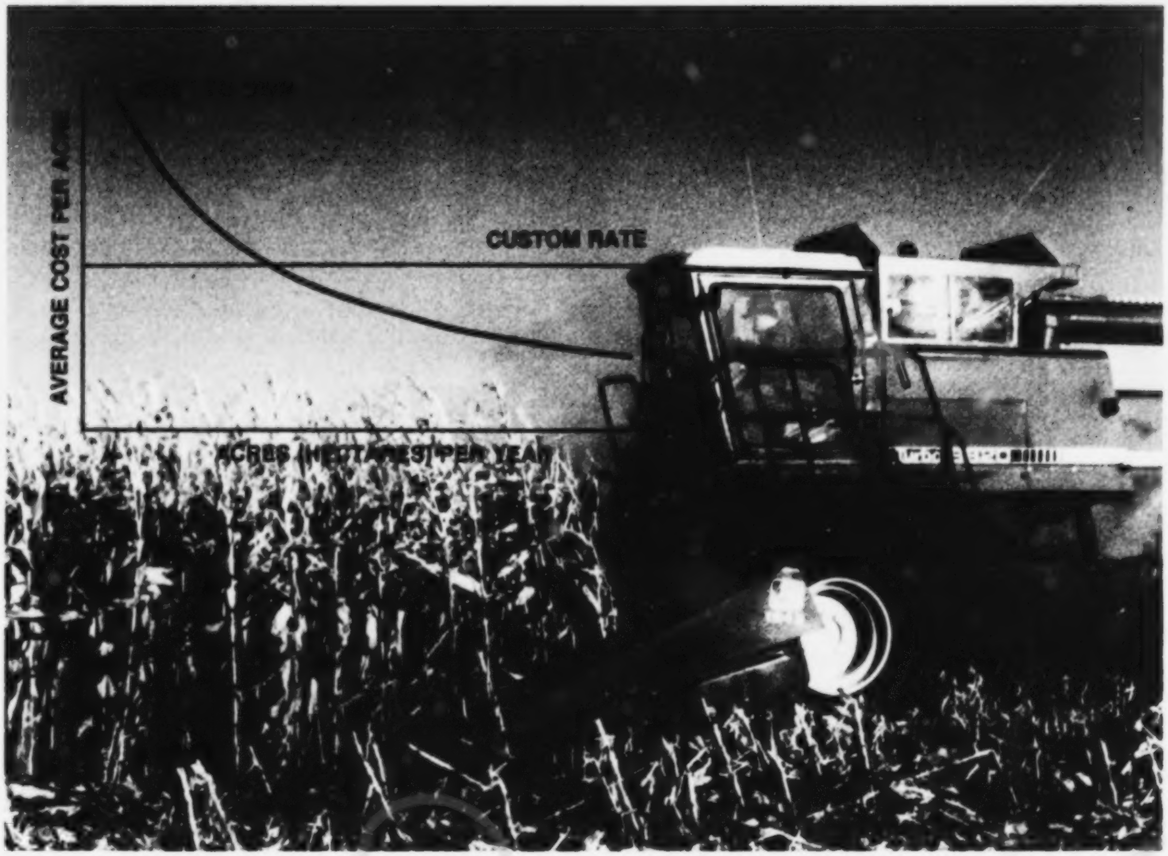


Fig. 2—For Small Annual Use, A Custom Operator May Provide The Least-Cost Method

operating costs at $3.50 an acre for the windrower (tractor, labor, fuel, oil, lubricants, repairs) (Fig. 4). This example is shown in metric equivalents beginning on page 136).

If the windrower has 300 acres of use per year, the difference between custom costs ($10.75 × 300 = $3,225) and operating costs ($3.50 × 300 = $1,050) would be saved. In this case, a savings of $2,175 over custom costs still resulted in being $325 short of paying machine ownership costs of $2,500 per year.

Because a savings of $7.25 on each acre is made, 345 acres ($2,500/$7.25) is needed to justify ownership. Using the formula to calculate the number of acres per year to justify machine ownership results in the same answer:

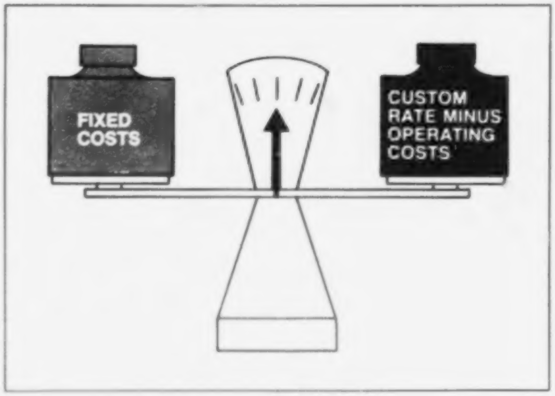
$$\text{"Break-even" acres} = \frac{\$2{,}500}{\$10.75 - \$3.50} = 345 \text{ acres}$$

To use this method for each situation, know or be able to determine the following:

- **Annual fixed costs**
- **Average operating costs**

Let's look at each of these costs in detail.

Fig. 3—In Justifying Ownership, Fixed Costs Must Be Balanced By Savings Over Custom Cost



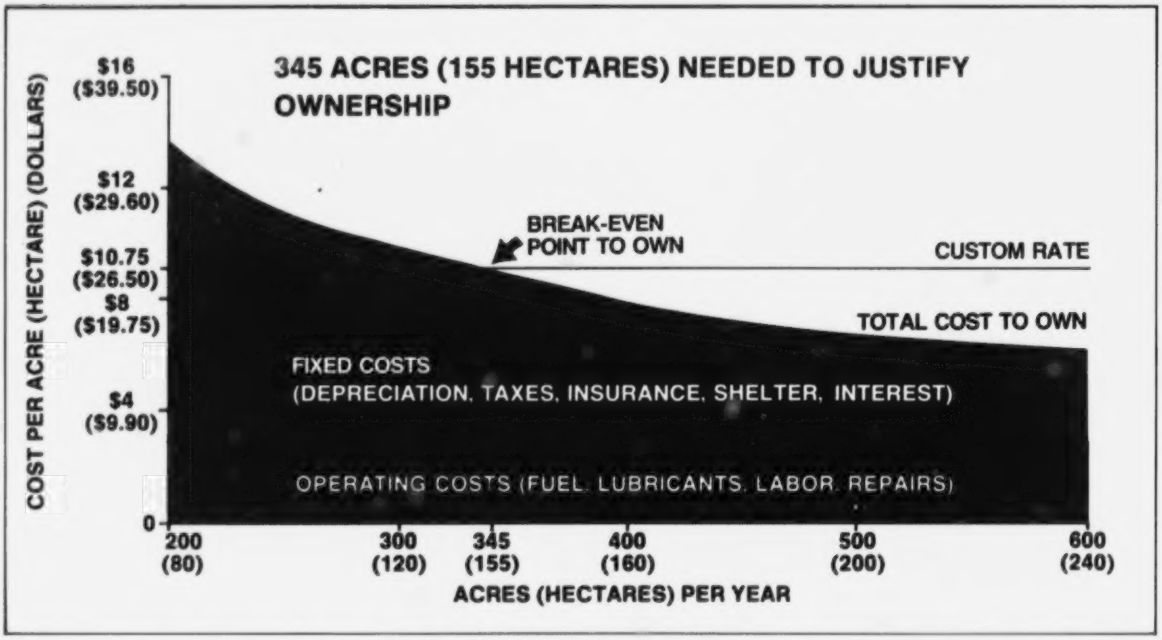


Fig. 4—Increasing Annual Use Helps Reduce Fixed Costs So You Can Justify Ownership

DETERMINING ANNUAL FIXED COSTS

The annual fixed costs can be determined by knowing the cost of the machine and length of ownership. If the machine is to be owned for 8 years, the average annual fixed cost is 14.41 percent of the new cost, as shown in Table 6, Chapter 6 (Fig. 5).

Fig. 5—Use Table 6 In Chapter 6 To Estimate Fixed Costs

TABLE 6

AVERAGE ANNUAL DEPRECIATION
AND FIXED COSTS AS A
PERCENTAGE OF ORIGINAL
LIST PRICE

Age,years	Tractors	Combines	All Others
1	46.50	40.96	52.20
2	29.00	27.26	32.15
3	22.92	22.33	25.06
4	19.70	19.62	21.25
5	17.64	17.81	18.76
6	16.17	16.46	16.96
7	15.03	15.38	15.55
8	14.11	14.49	14.41
9	13.34	13.72	13.45
10	12.68	13.04	12.63

The best bet is to be realistic in setting the length of ownership to estimate the average annual fixed cost. It would be a mistake to justify ownership on the basis of an eight-year life and then trade in a lesser period of time, such as four years.

The effect of ownership on the break-even point for the previous example of a windrower is illustrated in Figure 6.

DETERMINING AVERAGE OPERATING COSTS

Operating costs can be estimated from records or from the earlier chapters in this book. Remember that operating costs include:

- **Fuel**
- **Lubricants**
- **Labor**
- **Repairs**

DETERMINING TOTAL COSTS

Let's try another example of determining total costs, using a self-propelled combine. Assumptions include:

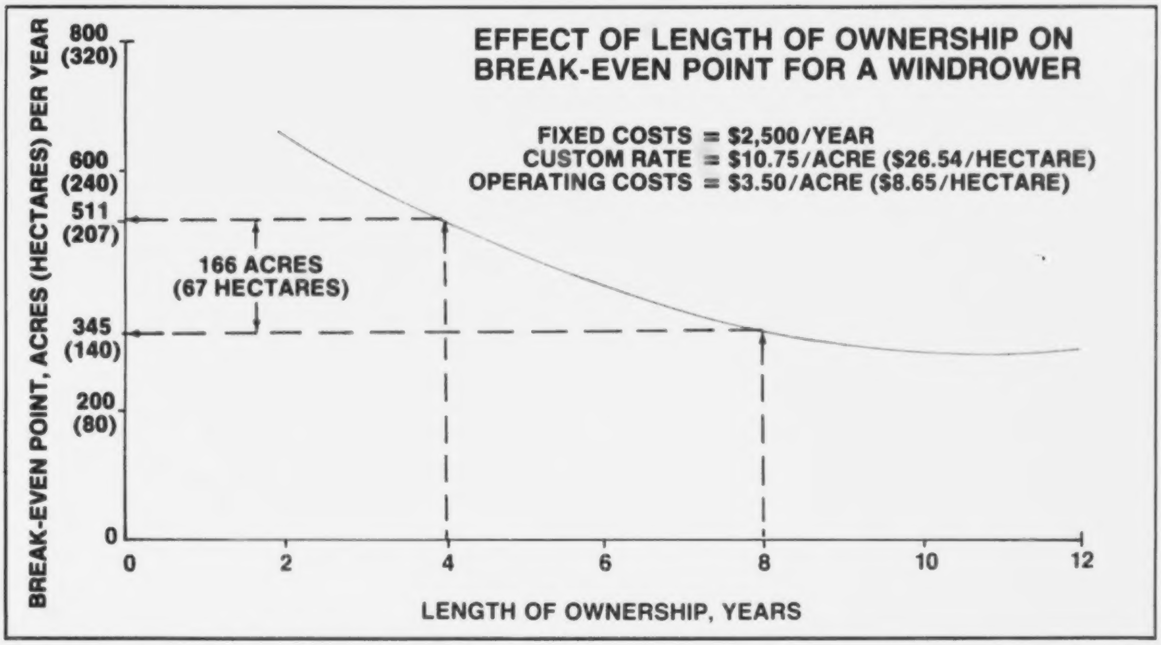


Fig. 6—Reducing Length Of Ownership Means You Must Greatly Increase Annual Use To Justify Ownership

- New cost for combine is $65,000
- Capacity is 6 acres (2.4 hectares) per hour in wheat.
- Custom rate is $15.00 an acre ($37.00 per hectare). (Custom rates will vary even for the same crop, depending on area, crop yield and supporting services provided, such as hauling grain a certain distance.)
- Fuel and lubricant costs for the combine are $6.90 an hour.
- Labor is $5.00 an hour.

Repair costs (Chapter 8) will be $45,500 over the life of the combine.

Assume the combine will be traded at 1,800 hours (between one-half and three-fourths wear-out life). Repair costs in this case will be $18,128 or will average $10.07 per hour.

Step 1—Determine Average Annual Fixed Costs

Assuming an 8-year life for the combine, 14.49 percent (table 6, Chapter 6) of the new cost of the combine is the average annual cost for depreciation, taxes, shelter, insurance and interest (fixed costs):

Average Annual Fixed Costs = 14.49% of $65,000
= .1449 x $65,000
= $9,418 per year

Step 2—Determine Operating Costs

Total operating costs for the combine are:

Fuel and lubricants	= $ 6.90 per hour
Labor	=$ 5.00 per hour
Repairs	= $10.07
TOTAL	= $21.97

Operating costs in this case are $21.97 per hour or $3.66 per acre ($21.97 per hour/6 acres per hour). The difference between the custom cost and your operating costs is therefore $11.34 per acre ($15.00 - $3.66).

Ⓜ Operating cost $9.04 per hectare ($21.97 per hour/2.43 ha/hr)

Difference between custom cost and your operating costs $27.96 per hectare ($37.00 - $9.04)

Step 3—Determine Break-Even Point

Using the formula for the break-even point in acres:

$$\frac{\text{Average Annual Fixed Cost}}{\text{Custom rate—Operating Cost}} = \frac{\$9{,}418}{\$15.00 - \$3.66}$$

$$\frac{\$9{,}418}{\$11.34} = 831 \text{ acres}$$

Ⓜ $$\frac{\$11{,}628}{\$37.00 - \$9.04} = 337 \text{ hectares}$$

In this case, 831 acres (337 hectares) are needed to justify ownership of the combine.

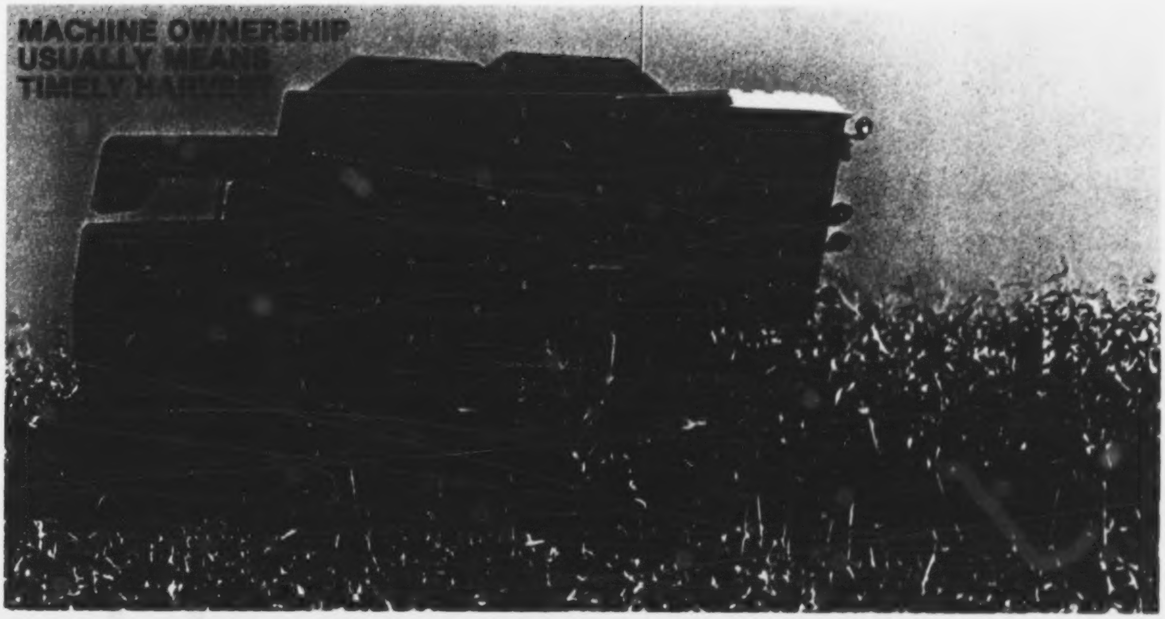


Fig. 7—Some Operators Prefer Owning Machinery To Ensure Timely Harvest

Now an interesting question arises. Suppose you only have 800 acres (324 hectares) to harvest, but are willing to accept the higher cost of ownership for the ability to harvest when the crop is ready (Fig. 7). What is the additional cost to own the combine instead of using a custom operator?

For 800 acres, $12,000 would be spent for custom harvesting ($15.00 x 800 acres). It costs $9,418 a year in fixed costs just to own the combine. Operating costs are $ 3.66 per acre which means total costs are $12,346 per year ($9,418 plus 800 x $3.66) for ownership of the combine. Therefore, the extra cost of ownership in this case is $346 per year over the custom combining charge. The extra cost per acre for ownership is $0.43 ($346/800 acres).

M Operating cost — $9.04 per hectare

Extra cost per hectare for ownership $1.06 ($344/324 hectares)

USING CUSTOM WORK TO HELP JUSTIFY OWNERSHIP COSTS

Still another question often comes up in regard to custom work versus owning. Some farmers like to do custom work in addition to their own work in order to justify ownership (Fig. 8). By determining the difference between the total work on your farm and the break-even point for machine ownership costs, the additional acres of custom work needed can be calculated.

In our previous example, the difference between 832 acres (the break-even point), and 800 acres (the amount of work on your farm), is 32 acres — the amount of custom work needed to justify ownership (Fig. 8).

M 336 ha - 324 ha = 12 ha

ESTABLISHING A RATE FOR CUSTOM WORK

Establishing a rate for custom-work charges depends on several variables, including:

- *Size of the field*
- *Travel distance from home base or last job*
- *Difficulties due to crop or field conditions*
- *Labor costs*
- *Profit-and-risk margins*

The approach to setting a custom rate is basically a matter of accurately estimating costs, then tacking on a margin for profit and risk. An adjustment for the specific situation is the final step.

Let's consider the situation of a custom business expected to return a profit (Fig. 9). In this case, the procedure consists of three steps:

1. **Estimating annual use.**
2. **Determining the basic cost.**
3. **Adding on the margin.**

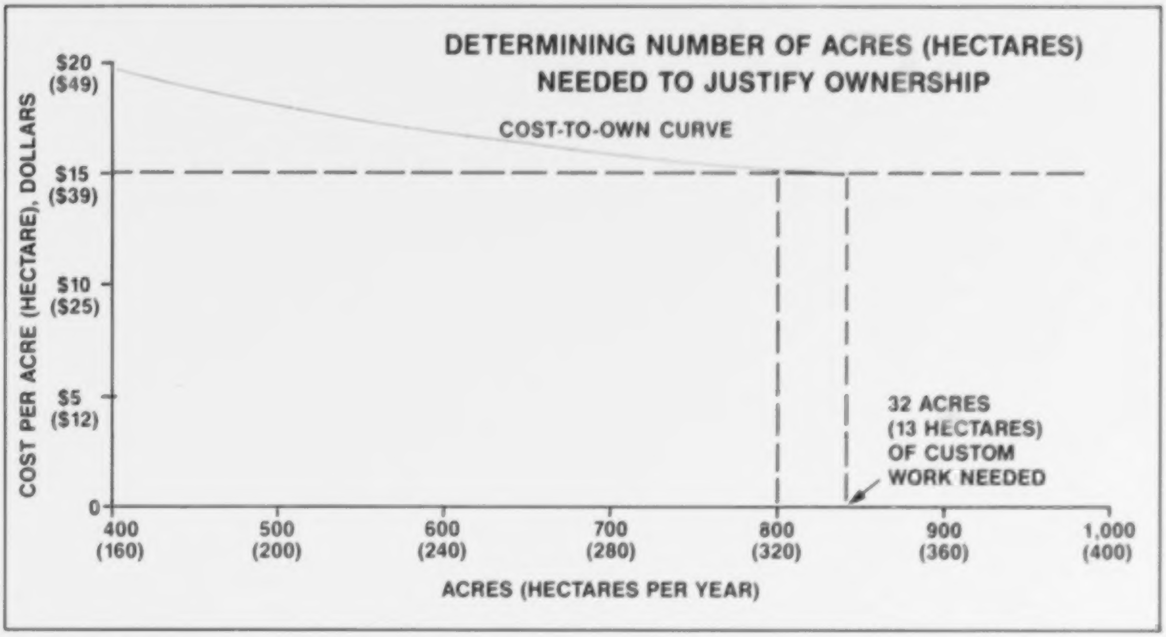


Fig. 8—Owning Machinery Can Be Justified By Doing Some Custom Work

Fig. 9—Some Machinery Owners Do Only Custom Work

As an example, suppose you want to run a custom wheat-combining operation, and plan to buy a $75,000 combine that can cut 8 acres (3.25 ha) of wheat per hour in average conditions.

Labor is $5.00 per hour. Total annual use is estimated at 300 hours per year. The combine has a 140-horsepower (105-kW) diesel engine that averages 7 gallons of fuel per hour during operation. The fuel costs $1.00 per gallon ($0.26 per liter).

Step 1—Determine Annual Use.

Annual use is already estimated at 300 hours per year.

Step 2—Determine Basic Costs.

From information in Chapter 10, we determined the combine could be owned 8 years or 2,000 hours, whichever comes first. In this case, assume the combine would be owned 8 years. The fixed costs plus repair costs is $0.678 per hour per $1,000 of cost (Appendix).

The fixed costs plus repair costs for the $75,000 combine is:

$75,000 divided by $1,000 x $0.678 = $50.85

Fuel cost would be:
7 gallons per hour x $1.00 per gallon = $7.00 per hour

Ⓜ 26.5 liters per hour x $0.26 per liter = $6.89 per hour

Add 10 percent of fuel cost for lubricant cost to obtain total fuel and lubricant cost:

$7.00 + (.10 x $7.00) = $7.70 per hour

SUMMARY OF COSTS:

Fixed costs plus repairs = $50.85 per hour

Fuel and lubricant cost = $ 7.70 per hour

Labor = $ 5.00 per hour

TOTAL = $63.55

At 8 acres (3.25 ha) per hour, the cost would be:

$63.55 divided by 8 = $7.94 per acre

Ⓜ $63.55 divided by 3.25 = $19.55 per hectare

The basic total cost is $7.94 per acre ($19.55/ha), including all fixed costs, fuel, lubricants and labor.

Step 3—Add The Profit-And-Risk Margin.

Determining the profit-and-risk margin is a tricky procedure (Fig. 10). This margin may range from 20 to 60 percent depending on the complexity of a machine. A complex machine like a combine has a much greater chance for a breakdown than a simpler tool like a disk harrow.

In this example, a profit-and-risk margin of 40 percent might be appropriate for the combine.

The custom rate charge would be calculated as follows:

$7.94 + (0.40 x $7.94) = $ 11.11 per acre

Ⓜ $19.55 + (0.40 x $19.55) = $27.37 per hectare

At this point, a likely custom rate would be set at $12.00 per acre ($30.00/ha). Adding charges for equipment and labor to support the operation, such as trucks, may result in a final custom charge closer to $15.00 per acre ($37.00 per hectare) in this example.

This example just illustrates one procedure that can be used for setting custom rates. The markup for risk and profit depends on individual situations. If there is a lot of competition, the margin may be quite small. If there is little competition and the operation is a fairly new method, the custom price may be quite high. Information in Table 1 can be used as a guide to help compute margin for custom rates.

TABLE 1

CUSTOM WORK CHARGES

Typical Operation	Average Custom Charges
Light Tillage (Very little risk, favorable field conditions)	Cost plus 20 to 30 percent
Plowing or Chiseling (Average field conditions)	Cost plus 30 to 40 percent
Medium to Heavy Disking (Average risk)	
Hay and Silage Operation (Heavy risks)	Cost plus 40 to 50 percent
Combining (Severe field conditions)	

CALCULATING AMOUNT OF CUSTOM WORK NEEDED TO JUSTIFY OWNERSHIP

Quite often the question is asked, "how much would I need to use a piece of equipment for custom work to justify owning it?" By knowing how to figure costs, such an analysis is possible (Fig. 11).

Suppose you are thinking of buying a baler to do custom work and want to know how many bales it would take to break even on costs. Here is the situation:

- *Baler costs = $11,000*
- *Tractor costs = $9.00 per hour*
- *Labor cost = $5.00 per hour*
- *Custom charge = $0.50 per bale*

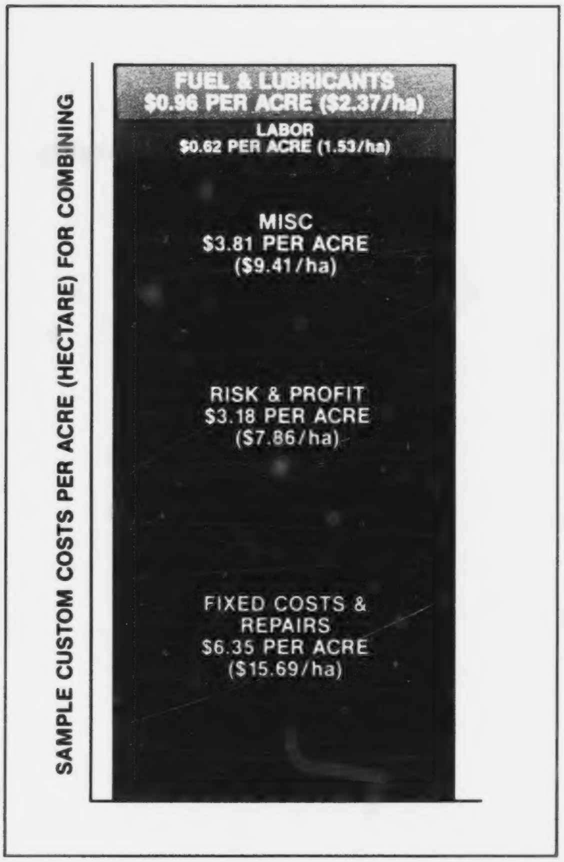


Fig. 10—Custom Rates Should Include A Charge For Risk And Profit

- *Overall capacity = 150 bales per hour*
- *Wire cost = $0.20 per bale*

First, let's figure the operating cost per bale:

COST PER HOUR:

Tractor = $9.00 per hour
Labor = $5.00 per hour
TOTAL = $14.00 per hour

$$\text{Tractor and labor costs} = \frac{\$14.00 \text{ per hour}}{150 \text{ bales per hour}}$$

$$= \$0.09 \text{ per bale}$$

Add wire costs of $0.20 per bale for a total operating cost of $0.29 per bale.

The next step has an important principle. The break-even point to own the baler for the custom baling operation will occur when the total savings in operating costs is equal to the average annual fixed costs.

Using information from Chapter 6 we can determine the average fixed costs. For fully scheduled custom baling operations, ownership could range from two to four years. Let's take a three-year ownership period as an example.

Average annual fixed costs for 3 years would be 25.06 percent. If the baler costs $11,000, the average annual fixed costs would be:

.2506 x $11,000 = $2,756 per year (Fig. 12)
The difference between the custom charge and the operating cost is $0.21 per bale ($0.50 - $0.29).
$2,756 divided by $0.21 = 13,124 bales

At 150 bales per hour, the break-even point would come at 87.5 hours:

13,124 bales divided by 150 bales per hour = 87.5 hours

In other words, the average annual fixed costs would be paid off at 87.5 hours or after 13,124 bales. The profit chart follows:

SAMPLE BALING PROFIT CHART

Hours	Bales	Net Profit
87.5	13,124	Break-Even
150	22,500	$1,970
200	30,000	$3,544
250	37,500	$5,119
300	45,000	$6,694
300	60,000	$9,844

There are some important observations that can be made from this example. First of all, *the greater the volume, the greater the profit*. In this case, each bale after the break-even point provided a clear profit of $0.21. So a custom operator should be well organized and produce a high output per hour.

Secondly, in setting a price for custom work, take into consideration travel distance from the home base, field conditions, crop yield and other things that might affect daily capacity. It is far better to invest money elsewhere than to do custom work at such a low rate that expenses are barely recovered each year.

Fig. 11—An Accurate Cost Analysis Is Essential In Custom Work

SUMMARY

A custom operator may be the least-cost choice compared to owning a machine in some cases. One advantage of hiring a custom operator is that less money is tied up in ownership of machinery. One disadvantage may be the lack of timeliness.

The formula used for calculating the number of acres or hectares needed per hear to justify ownership of a machine is:

$$\frac{\textbf{Average Annual Fixed Costs}}{\textbf{(Custom Rate) - (Operating Cost Per Acre or Hectare)}}$$

To estimate the costs involved in a custom operation, there are three steps:

1. *Estimating annual use*
2. *Determining the basic cost*
3. *Adding on the margin*

METRIC EQUIVALENTS

DETERMINING AND COMPARING COST

The following example, in metrics, is roughly equivalent to the example shown in U.S.A. customary figures on page 129.

Custom operator charges — $25.00 per hectare

Cost per year to own pull-type windrower — $2,500

Operating cost for windrower (tractor, labor, fuel, oil, lubricants, repairs) — $8.75

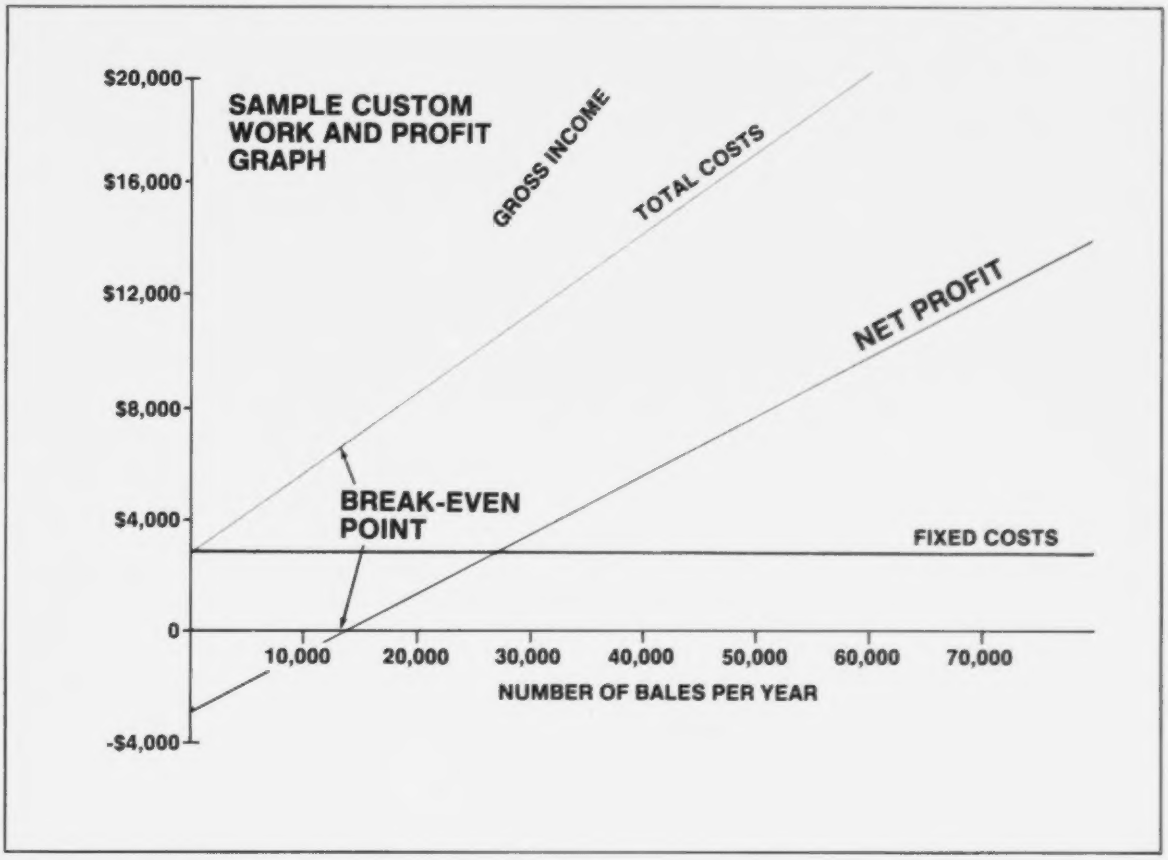


Fig. 12—The Amount Of Custom Work Affects Profit

If the windrower has 120 hectares of use per year, the difference between custom costs ($25.00 × 120 = $3,000) and operating costs ($8.75 × 120 = $1,050) would be saved. In this case, a savings of $1,950 over custom costs still resulted in being $550 short of paying machine ownership costs of $2,500 per year.

Because a savings of $16.50 per hectare is made, 155 hectares ($2,500/$16.25) is needed to justify ownership. Using the formula to calculate the number of hectares per year to justify machine ownership results in the same answer:

$$\text{"Break-even" hectares} = \frac{\$2,500}{\$25.00 - \$8.75} = 155 \text{ hectares}$$

ADDING CUSTOM WORK TO REDUCE COSTS

This chapter has dealt primarily with the procedure for establishing custom rates for a business. A similar procedure may be used to establish charging rates for part-time custom work.

Part-time custom work can be beneficial to both parties. If you have equipment that is not fully utilized it means that your fixed costs are probably higher than they should be. On the other hand if your neighbor lacks sufficient capacity to get everything done when it is needed then they can benefit from hiring you for custom work.

For example, suppose that you have a tractor and a plow (Fig. 13) that are in good condition. The tractor is used 500 hours a year and the plow 75 hours a year. Your neighbor wants you to plow 120 acres for him.

For 10 years you have owned a 100 hp tractor that cost $36,000. Your 8-year old plow with the capacity to plow 3 acres/hour cost your $6,000.

What should you charge him? How much will it lower your costs?

Current tractor costs:

Fixed costs $36,000 divided by 1,000 x .313 (from Table 1, Appendix)

Fixed costs = $11.27/hour
Fuel and Lube 100 x .044 x $1.00 x 1.1 = $ 4.84/hour
Labor =$ 5.00/hour
TOTAL =$21.11/hour

Current plow costs:

Fixed costs — $6,000 x $2.200 = $13.20/hour

Total costs, tractor and plow = $34.31/hour

These are your current costs.

Based on Table 1 you should charge from 20 to 30 percent over your costs. You might charge 20 percent because plowing usually causes minimal damage to your equipment. You also are not doing custom work as a full-time occupation.

$34.31 + $6.86 (20 percent of $34.31) = $41.17 per hour.

If you divide $42.00 per hour (41.17 rounded) by 3 acres per hour, you would charge $14.00 an acre for the plowing.

The total job is 120 acres x $14.00 an acre or $1,680.

Your out-of-pocket costs are fuel and lubricant charges plus your labor.

Plowing 120 acres would take 40 hours.

40 hours x ($4.84 + $5.00) = $394

$1,680 - $394 = $1,286 cost reduction

You could consider the $1,286 as reduction of costs for your current equipment or as added income. Either way, part-time custom work can be profitable.

CHAPTER QUIZ

1. When would you use a custom operator instead of buying a machine? (Give two examples.)

2. When would you buy a machine rather than using a custom operator? (Give two examples.)

3. How many acres per year would you need to justify ownership of a self-propelled combine if average annual fixed costs are $12,000, the custom rate is $13.00 per acre and your operating costs are $3.25 per acre?

4. Suppose you have 600 acres of work per year. Could you justify the combine described in Problem 3? If not, what would be the added cost per acre to own rather than use a custom operator?

5. You own a self-propelled windrower that has a basic cost of $40.00 per hour. Capacity is 5 acres per hour. What would you suggest as a charge for custom work?

Ⓜ 6. How many hectares of wheat must you combine per year to break even for doing custom work if:

a) You charge $40.00 per hectare.

b) Capacity is 3.25 hectares per hour.

c) Repair costs are $4.00 per hour of use.

d) Labor is $5.00 per hour.

e) Fuel and lubricant costs are $8.00 per hour.

f) The combine costs $75,000; you use it 400 hours per year, and will trade in 4 years.

13

Comparing Ownership, Leasing and Rental Costs

Fig. 1—Knowing When To Lease Or Rent Equipment Instead Of Buying Equipment Is An Important Management Skill

INTRODUCTION

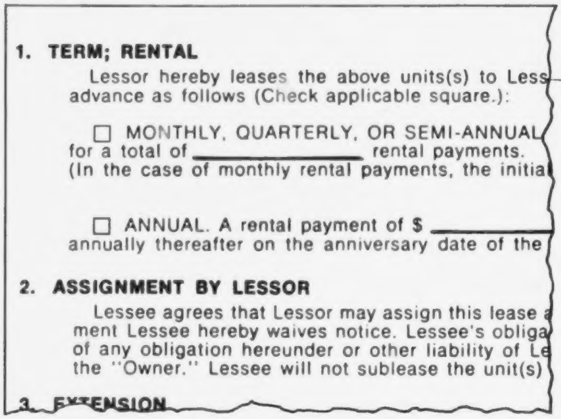
Good machinery management also involves the ability to evaluate the different alternatives to ownership (Fig. 1). Leasing or renting equipment are two such alternatives. This chapter will provide a comparison of the costs of leasing and renting machinery to the costs involved in ownership.

When a decision is to be made on leasing or renting a machine instead of buying one, using available and up-to-date information is important. This is an important point due to constantly changing interest rates, different leasing and rental arrangements, and Internal Revenue Service regulations on deductions.

Just as it is important to stay informed on market prices to realize the greatest profit for a product, it is also important to stay informed on the different changes that affect the cost of renting, leasing or owning machinery.

To help establish some common definitions for use in this chapter, we will use the term "lease" to apply to an arrangement lasting longer than one year—usually two or more years. "Rental" will refer to a short-term arrangement usually lasting less than one year—one day, one week, one month or several months (Fig. 2).

Fig. 2—The Term "Rent" Usually Applies To A Period Of Time Lasting Less Than 12 Months



1. TERM; RENTAL

Lessor hereby leases the above units(s) to Less
advance as follows (Check applicable square.):

☐ MONTHLY, QUARTERLY, OR SEMI-ANNUAL
for a total of ______________ rental payments.
(In the case of monthly rental payments, the initial

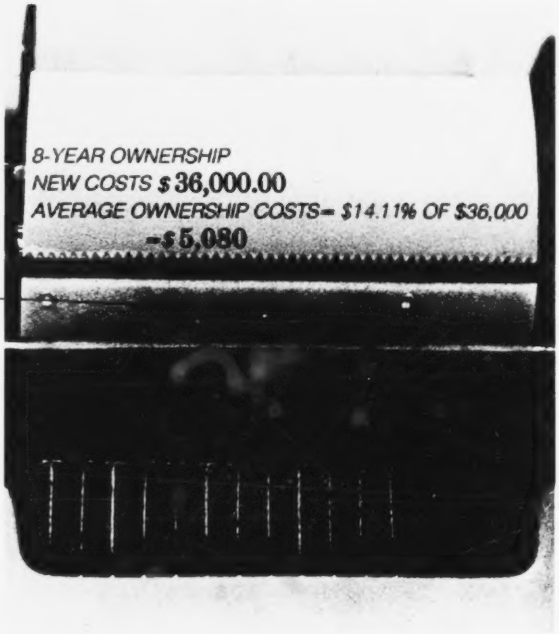
☐ ANNUAL. A rental payment of $ ____________
annually thereafter on the anniversary date of the

2. ASSIGNMENT BY LESSOR

Lessee agrees that Lessor may assign this lease
ment Lessee hereby waives notice. Lessee's obliga
of any obligation hereunder or other liability of Le
the "Owner." Lessee will not sublease the unit(s)

3. EXTENSION

Fig. 3—The Best Way To Make Machinery Decisions Is To Know How To Estimate Ownership Costs



8-YEAR OWNERSHIP
NEW COSTS **$ 36,000.00**
AVERAGE OWNERSHIP COSTS= $14.11% OF $36,000
=$ 5,080

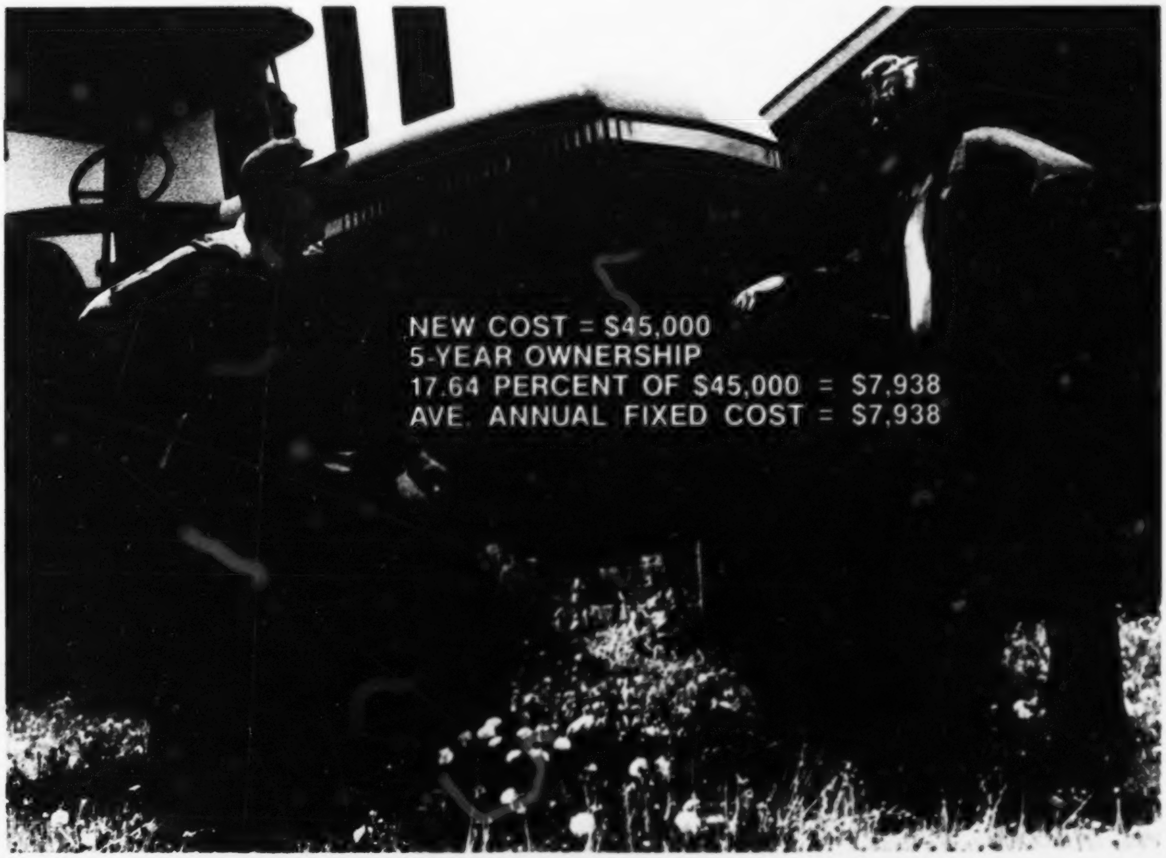

NEW COST = $45,000
5-YEAR OWNERSHIP
17.64 PERCENT OF $45,000 = $7,938
AVE. ANNUAL FIXED COST = $7,938

Fig. 4—Average Annual Fixed Costs For A $45,000 Tractor Owned For 5 Years

COMPARING LEASING COSTS TO OWNERSHIP COSTS

The best starting point for any comparison of leasing and owning machinery is to establish accurate ownership costs (Fig. 3). In our comparison, we will assume that any major piece of agricultural equipment will either become obsolete or worn-out in eight years. This approach uses a shorter term of ownership than some cost-analysis methods. The eight-year maximum ownership period is more realistic for the type of farming where leasing or renting may have a practical application. Costs involved in our comparison include:

- **Fixed costs**
- **Repair costs**
- **Fuel, lubricant and labor costs**

First, we will review these costs and then compare them for both leasing and owning machinery.

FIXED COSTS

As discussed in Chapter 6, fixed costs for machinery include:

- **Depreciation**
- **Taxes**
- **Shelter**
- **Insurance**
- **Interest**

These fixed or ownership costs for tractors and machinery are shown in Table 1. They include a declining-balance depreciation schedule, a ten percent interest charge and a four percent charge for other overhead costs.

TABLE 1

AVERAGE ANNUAL DEPRECIATION AND FIXED COSTS AS A PERCENTAGE OF ORIGINAL LIST PRICE

Age, years	Tractors	Combines	All Others
1	46.50	40.96	52.20
2	29.00	27.26	32.15
3	22.92	22.33	25.06
4	19.70	19.62	21.25
5	17.64	17.81	18.76
6	16.17	16.46	16.96
7	15.03	15.38	15.55
8	14.11	14.49	14.41
9	13.34	13.72	13.45
10	12.68	13.04	12.63

Calculating Fixed Costs

Let's review how to calculate fixed costs, which were covered in Chapter 6. Suppose we want to find what the average annual and the total fixed costs are to own a $45,000 tractor for 5 years.

Fig. 5—Fuel And Lubricant Costs Are The Same Whether The Machine Is Leased Or Owned

Using the information in Table 1, we find that the average annual fixed cost for a tractor is 17.64 percent for a period of 5 years. First, calculate the average annual fixed cost:

.1764 x $45,000 = $7,938

Now the total fixed costs for 5 years can be calculated (Fig. 4):

5 years x $7,938 = $39,690

REPAIR COSTS

Whether the machine is owned or leased, the person using it usually pays the normal repair costs. For more accuracy, repair costs should be calculated and included in comparisons because total repair costs increase with use. Short-term leased tractors would have a considerably lower hourly repair cost than a tractor owned for its complete useful life.

FUEL, LUBRICANT AND LABOR COSTS

Because fuel, lubricant and labor costs are the same for a machine whether it is leased or owned, do not include them in cost estimates (Fig. 5).

But to complete the total cost picture for tractors, average fuel consumption can be estimated by multiplying the maximum PTO horsepower of the tractor by 0.044 for diesel, 0.068 for gasoline and 0.080 for LP-Gas.

A diesel-engine tractor rated at 100 maximum PTO horsepower would have an estimated fuel consumption of 4.4 gallons per hour (100 hp x 0.044) as the average hourly rate for year-round operations. Lubricant costs are assumed to be equal to 10 percent of the fuel cost.

COMPARING COSTS

As a basis for comparing leasing versus ownership, fixed costs plus repairs can be combined for three levels of new tractor costs:

- *$400 per horsepower*
- *$350 per horsepower*
- *$300 per horsepower*

Assuming annual use ranges from 400 to 1200 hours per year, the average cost-per-hour per horsepower is shown in Table 2. In metric equivalents, Table 15 on page 170 shows the average cost-per-hour per kilowatt.

These data points can be used to plot a graph for comparing ownership costs against leasing costs (Fig. 6). In computing these cost figures, the *ownership period* was assumed to be 8,000 hours or 8 years, whichever came first. Interest was charged at 14 percent and the other fixed costs at 4 percent of the remaining value.

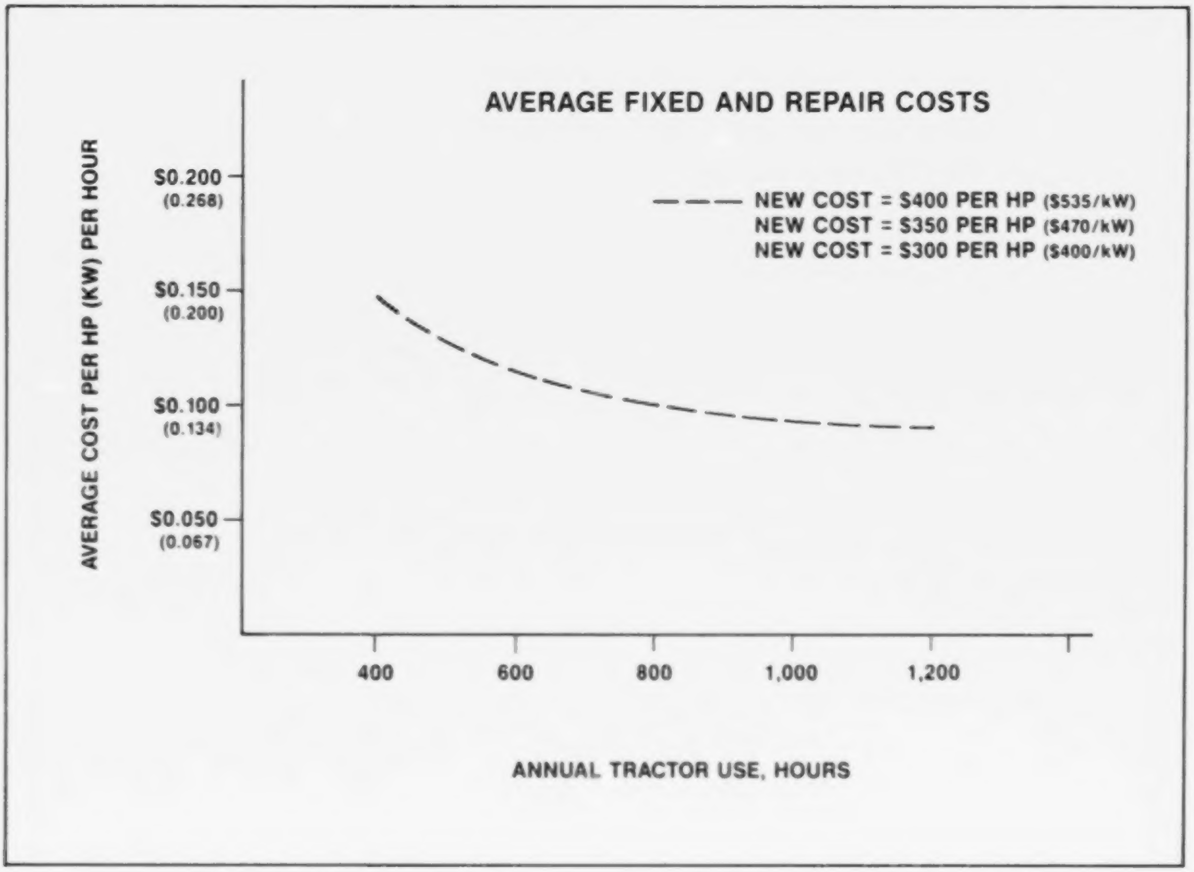


Fig. 6—Fixed Cost And Repair Costs Versus Annual Use

As an example, let's determine the fixed cost plus repair cost for a 150-horsepower (110-kW) tractor that costs $45,000 new and is used 800 hours per year. We also want to know what the average annual costs will be.

First, let's find the new cost per horsepower:

$$\frac{\$45{,}000}{150\text{ hp}} = \$300 \text{ per horsepower}$$

By using the information in Table 2 (Table 15, page 170 for metric) or the graph in Figure 6, we have a cost of $0.078 per hour per horsepower for a 150-horsepower, $45,000 tractor (Fig. 7). Next, we calculate the average annual costs:

$0.078 x 150 hp x 800 hours = $9,360 per year

Ⓜ $0.104 x 112 kW x 800 hours = $9,360 per year

The $9,360 annual cost (exclusive of fuel, lubricant and labor costs) could be used as the basis for comparing ownership costs to available lease rates. The graph in Figure 6 is useful for checking the feasibility of a given leasing or rental opportunity.

Let's use another comparison of ownership and leasing costs. This time, compare the hourly cost per horsepower for a $35,000, 100-horsepower (75-kW) tractor as shown by the information in Table 3. See Table 16, page 171 for metric equivalent to Table 3.

Table 2

AVERAGE FIXED AND REPAIR COSTS

PER HORSEPOWER HOUR

New Cost per hp	Annual Tractor Use, Hours Per Year 400	600	800	1,000	1,200
$300	$0.111	$0.088	$0.078	$0.071	$0.067
$350	$0.129	$0.103	$0.091	$0.083	$0.078
$400	$0.146	$0.117	$0.104	$0.094	$0.089

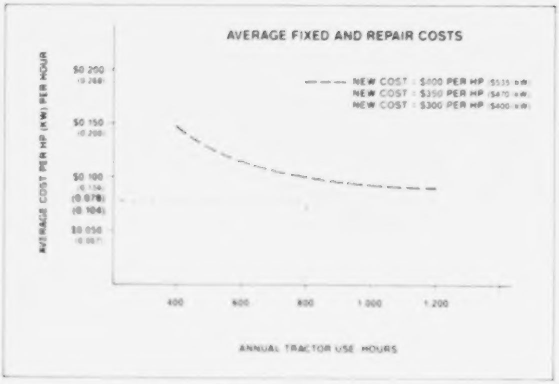


Fig. 7—Fixed Cost Plus Repairs For A 150-Horsepower, $45,000 Tractor Used 800 Hours Per Year

TABLE 3

SAMPLE HOURLY COST*

PER HORSEPOWER

$35,000, 100-HP (75-kW) TRACTOR

	Annual Use, Hours				
	400	600	800	1,000	1,200
Cost to Own	$0.129	$0.103	$0.091	$0.083	$0.078
3-year lease	$0.230	$0.166	$0.134	$0.115	$0.103
4-year lease	$0.215	$0.153	$0.124	$0.107	$0.096
5-year lease	$0.196	$0.141	$0.115	$0.101	$0.092

*Lease cost includes annual lease costs plus repairs, taxes and insurance. Cost prorated over life of tractor.

TABLE 4

EXAMPLE OF AVERAGE

ANNUAL COSTS

$35,000, 100-HP (75-kW) TRACTOR

	Hours Per Year		
	800	1,000	1,200
Cost to Own	$7,280	$8,300	$9,360
3-year lease	$10,720	$11,500	$12,360
4-year lease	$9,920	$10,700	$11,520
5-year lease	$9,200	$10,100	$11,040

Notice that owning the tractor proved to be more profitable than leasing in all cases. However, the differences at high annual uses for a four-year lease are not as great as for a two- or three-year lease and lower annual use. Some leases will specify a maximum annual usage, after which the annual leasing cost increases.

The owner's leasing comparisons for the $35,000, 100-horsepower (75-kW) tractor are shown in Table 4 for annual uses of 800, 1,000 and 1,200 hours per year.

As mentioned before, there are many different kinds of leasing arrangements, but seldom do they show a cost advantage in a head-on comparison. The previous example, while not intended to represent average available leasing costs, does indicate the effect of the length of the lease and annual use on hourly cost.

COMPARING RENTAL COSTS TO OWNERSHIP COSTS

The rental of tractors and other farm equipment is becoming increasingly popular with the farmer who is short on capital or has only short term needs. It also can increase the returns of the machine dealer who leases the equipment.

Typical rental practices include the following:

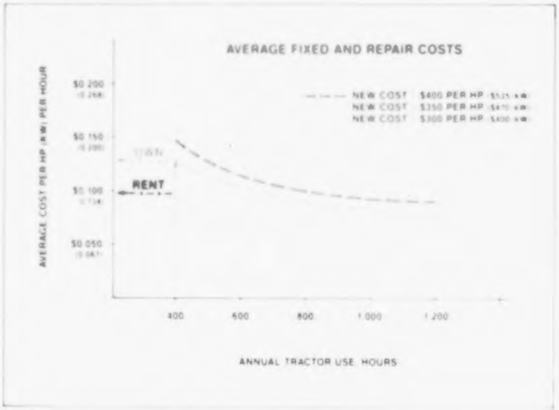
1. Rental may be by the hour, acre, day, week or month. A day is 8 hours, a week is 40 hours and a month is 176 hours.

2. The customer is responsible for maintenance, service, fuel, and lubricants.

3. The dealer is responsible for furnishing equipment in good operating condition. Most rental rates are based on new or nearly new equipment.

4. The customer pays the delivery costs.

Fig. 8—The Graph In Figure 6 Can Be Used To Compare Rental Costs To Ownership Costs



Rental rates vary. This is due to climatic factors, operator skill and reputation, and the severity of service.

The following example illustrates one way that renting offers a solution to a serious problem.

Example: In January you realize that you are far behind in tillage due to above normal rainfall in the previous fall which prevented customary fall tillage. You know that you do not have enough tractors of the right size to get caught up when the weather allows you to start work in the spring. A two-wheel-drive tractor of 150 horsepower, rented for one month, would solve your problem. You could buy the tractor. The problem is that it will be used only 400 hours a year. A new tractor lists for $52,500 ($350 per horsepower). What should you do?

Step-by-step solution:

1. What would it cost to rent the tractor for one month?

The dealer quotes you a figure of $2,600.

2. Determine the cost to own.

Since you pay operating costs you need to compare fixed costs plus repairs (the basis for the rental)

Assume you will own the tractor at least 8 years.

Table 2 shows the cost per hour per horsepower for ownership to be $0.129

Your cost = $0.129 x 150 hp x 400 hours per year

= $7,740 per year

Cost per hour = $0.129 x 150 = $19.35.

3. Compare renting to owning.

Ownership costs for one month (176 hours)

$19.35 x 176 = $3,406

Rental costs = $2,600

The advantage to rent for one year = $3,406 - $2,600 = $806

You could also use Fig. 6 for a quick comparison.

Using the curves in Figure 6, draw one line horizontally at $0.098 ($2,600/150hp/176 hours) the cost per horsepower per hour if the tractor were rented (Fig. 8).

Next, locate the point on the $350-per-horsepower curve where it is intersected by a vertical line drawn upward from 400 hours per year (Fig. 8). The first line, drawn horizontally at $0.098 to indicate the rental cost per horsepower-hour, intersects the cost curve at a lower point than the line drawn vertically for owning the tractor.

This example shows a clear cut advantage for renting. Local conditions and situations vary considerably, so you need to check with local dealers and compare your costs to own.

WHEN RENTING IS THE BEST ALTERNATIVE

Leasing is usually of greatest benefit to the high-annual use and limited-capital situation; however, renting agricultural machinery for short periods may be beneficial for:

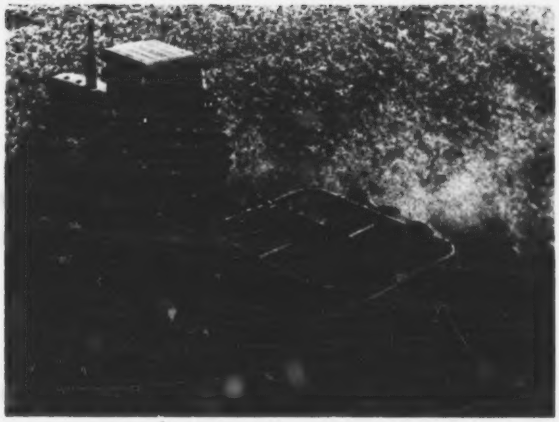


Fig. 9—Renting May Be The Best Answer For The Low Annual Use Situation

- *Low annual use, specialized operations (Fig. 9)*
- *Deferring capital expenditure*
- *Use in periods of uncertainty*
- *Helping complete important operations on time (Fig. 10)*

Fig. 10—Renting May Be A Good Way To Help Get Important Operations Done On Time

One example of the proper use of renting would be in the first year of a growth situation when all capital or borrowing power may be tied up in buying land, seed, fertilizer, irrigation or just meeting the payroll.

Renting can be a very good alternative if you are short on capital or borrowing power.

There are two primary considerations that should influence decision making on your equipment. First, be sure that you can get operations done on time. Second, keep costs to a minimum without reducing production. You will be in better shape to make the right decisions if you (1) Know your machinery costs and (2) keep a constant check on local rental rates.

WHEN OWNING IS THE BEST ALTERNATIVE

If capital is not a limiting factor and the size of the business is fairly stable, owning machinery will normally give a cost benefit (Fig. 11). It is also desirable to own a machine or tractor when there is little chance of it becoming obsolete by size or capability before it is worn out.

Income tax considerations must also be included in these decisions. When it comes to a final decision, check with an income tax consultant as individual cases can make a big difference. With a bona fide lease or rental, the entire cost is deductible. By owning machinery, depreciation deductions are restricted. Either method can lead to a sizable income tax advantage depending on the situation.

Fig. 11—For Most Normal Farming Situations, Owning Machinery Is The Most Economical Alternative

Even though all of the leasing or renting cost is tax deductible, purchasing new machinery at favorable times can sometimes be used to permit the high early years' depreciation to offset the costs of being in a high tax bracket.

In considering ownership versus leasing, someone has to pay for the ownership costs. If the dealer sells the machine, he has already taken all of the profit he will get on that machine. Total costs will be considerably less for the user if the machine is purchased rather than leased.

WHEN LEASING IS THE BEST ALTERNATIVE

There are some situations where leasing may be the best method of obtaining machinery. Some of the more important ones include:

- Short on capital, such as in expanding the size of the business.
- A short-term opportunity investment in the business occurs that will yield a greater return on capital than financing costs for purchasing equipment.
- The rate of return of the business is considerably higher than interest rates on borrowed capital.
- The future is uncertain and it is preferred to defer long-run commitments. However, the commitment to lease is the same as signing a sales contract as far as financial obligations are concerned.
- There is a definite reliability and operational advantage in having new late-model equipment, such as with leasing.
- There is uncertainty as to what size or model is needed in your farming situation.
- The owner is phasing out of business.

SUMMARY

Whether to own or lease machinery is a question that must be decided for each financial situation. In the long run, almost any route taken would eventually lead to owning equipment. But for alert managers, leasing can sometimes be used as a desirable management tool.

The greatest *advantage to owning* is to minimize machinery costs over the long term.

The greatest *advantage to leasing* is to provide a way to get important operations completed on time while deferring a major capital commitment.

The greatest *advantage to renting* is in covering low annual use operations while deferring capital expenditures.

How you choose between these three options will determine your success as a machinery manager. Good management is a result of considering all aspects of the three methods of obtaining machinery and making the best choice for your operation.

CHAPTER QUIZ

1. What is the primary difference between leasing and renting?

2. If you can rent a 125-horsepower tractor for $20.00 per hour, what is the cost per horsepower-hour?

3. List two primary reasons for leasing.

4. List two primary reasons for renting.

5. Why do most farmers own their machinery rather than lease or rent?

6. Your local dealer says he will lease a 75-horsepower tractor to you for $9,000 per year with a maximum use of 1,000 hours per year.

a) What would be the cost of leasing per horsepower hour, if you use it for 1,000 hours?

b) If you could buy the same tractor for $30,000, which would be more economical? By how much?

14

Starting Machinery Management

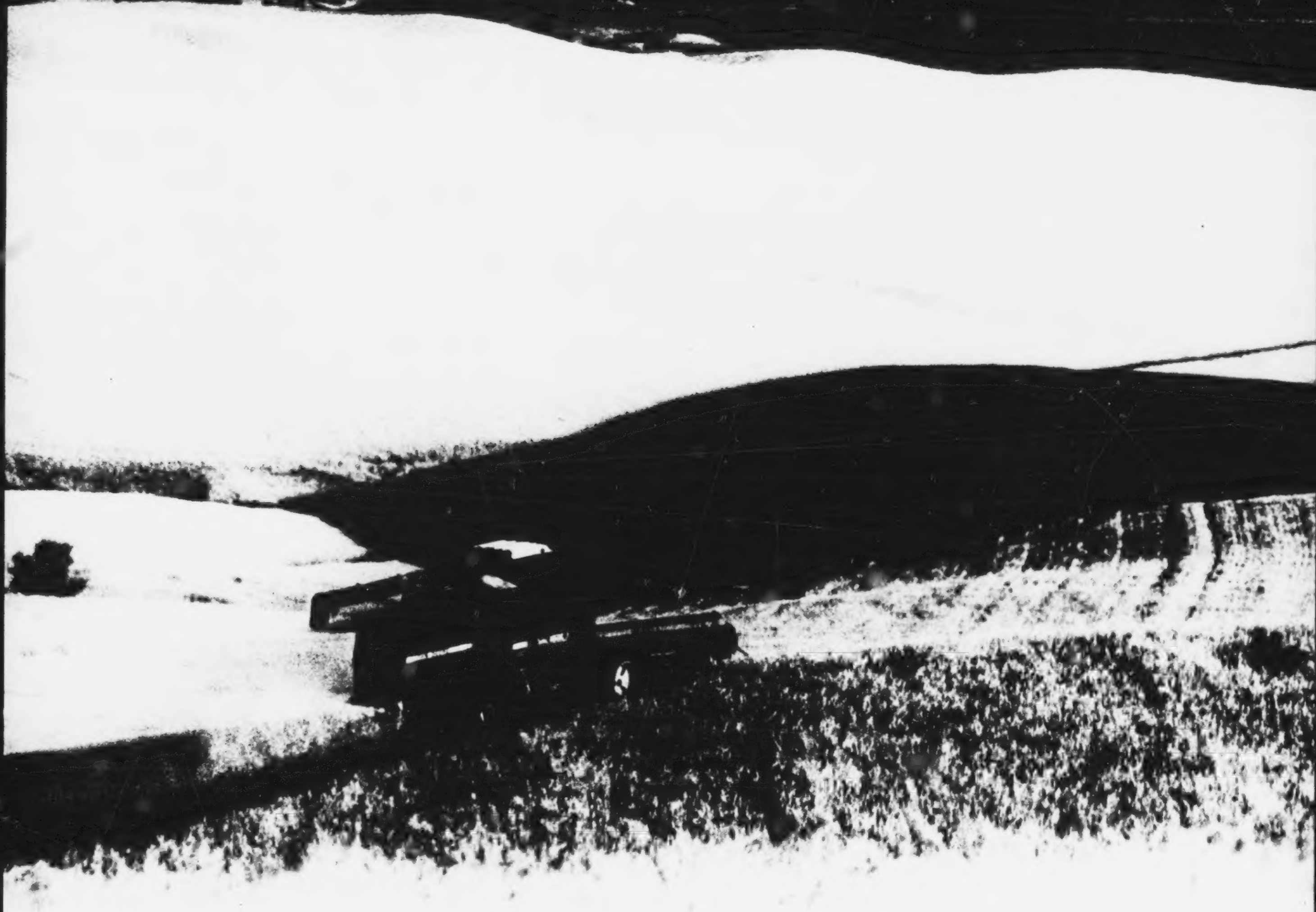


Fig. 1—Most Farms Vary Enough To Make Data On Each Operation Important To Machinery Management Decisions

INTRODUCTION

Now that the basics of machinery management have been presented in the preceding 13 chapters, it is important to begin developing these basics into a comprehensive machinery management program. Because no two farming operations are exactly the same, it is up to each manager to gather all of the information possible (Fig. 1).

Sources of information can include your own business records on the machinery already owned, extension divisions of universities, farm equipment dealers and other farm equipment related businesses. Remember that as much information as possible is needed to formulate the most effective and profitable machinery management program for each operation.

Many universities and some farm equipment companies now offer machinery management programs and services. In some cases, assistance consists of programming information into a computer to aid in arriving at machinery management decisions.

But even when a computer is involved in making decisions, the burden is still on the manager to provide a large part of the input information. The manager must also understand the principles of machinery management to more effectively adapt any advice and information to his operation.

The need for awareness of machinery management techniques is being recognized as a more important factor in farming for three reasons:

- **Higher ownership costs**
- **Higher labor costs**
- **Larger number of crop acres per operating unit**

The last reason given, larger number of crop acres per operating unit, leads to the most important concept of machinery management to understand—timeliness. Timeliness is completing a certain job, such as planting, within a certain time period after which equivalent losses become greater through either reduced yields or a less efficient harvest.

If lost time is calculated on certain high-importance operations, like planting, with timeliness figured in, it becomes easy to see that breakdowns, delays or undersized machines can cost hundreds of dollars per hour instead of just a few dollars per hour in unused labor (Fig. 2).

Although timeliness is an important management factor, *cash flow* is even more important. Planning machinery management decisions ahead of time will help maintain a good financial position.

DEVELOPING BASIC SKILLS

Let's discuss some basic management skills that should be developed as a base for later management decisions. These factors include:

- **Keeping accurate records**
- **Improving field efficiency**

Both are needed as an accurate base for any machinery management program. Let's review these factors and their direct effect on developing a profitable machinery management program.

KEEPING ACCURATE RECORDS

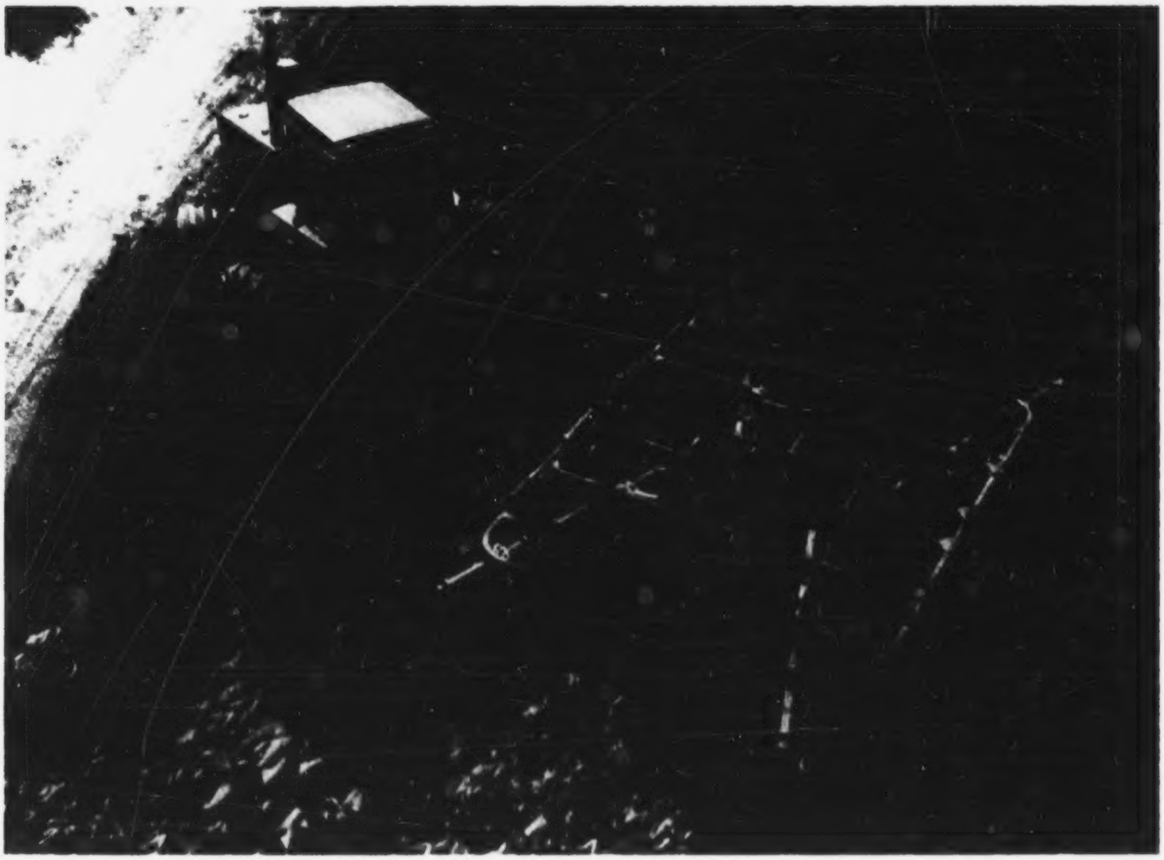
When it comes to machinery management decisions, knowing costs is important. The best way to determine costs is to start with your own accurate records. Record the hours of usage of various machines. Also, record the number of hours of productive field work obtained in various time periods (Fig. 3).

If an average of 85 percent or better of productive work is obtained in a given time period, it would probably be difficult to increase productivity to any great extent.

It is also important to know what specific calendar period should be used for each operation, such as plowing, disking, seedbed preparation and planting. Get a feel for the average number of working hours during each critical phase of operation. Then decide how much excess capacity and power is needed to hedge against the short work season that might come along because of bad weather or other factors.

Some experts say that a good method of calculating practical power requirements is to calculate the

Fig. 2—Lost Time Is Extremely Costly On Important Operations When Timeliness Factors Are Figured In



minimum power requirement and then increase that figure by 25 percent to size tractors properly.

Probably the greatest advantage of good record keeping is establishing guidelines directly related to being able to meet "timeliness" requirements such as planting and harvesting. Good records are a great aid in establishing machinery size and time requirements needed for best yields and crop results.

IMPROVING FIELD EFFICIENCY

The second step in evaluating your present machinery inventory is to improve field efficiency to the maximum point. The operator usually has the most influence on field efficiency and directly affects the percentage of work accomplished in a given time period.

By continually improving field efficiency, many average operators can increase the amount of work for a given time period by ten percent or more.

As discussed in Chapter 3, many machinery managers do not really concentrate management effort on improving field efficiency of their operations. Just slight improvements in field efficiency can make a big difference in the amount of work accomplished. For example, if an operator that is averaging 6 acres (2.4 ha) per hour with an offset disk can improve that average to 6.5 acres (2.6 ha) per day, an extra 5 acres would be disked in a 10-hour day.

Not only would the speed of the disking operation increase, but a gain in labor productivity per hour would also be made. Eliminating a few lost motions in field operations and other factors in operations can provide sizable returns and better prepare you to calculate how well you can handle important operations.

APPLYING MACHINERY MANAGEMENT SKILLS

When the most efficient use is being made of present machinery and labor availability, several reasons

Fig. 3—Complete And Accurate Records Are Essential To Making Machinery Management Decisions

Key Machine Cost Analysis
NOTES
May 1--
May 2--
May 3 -- Planted 15 Acres in 2 Hrs.
May 4 -- Planted 75 Acres in 10 Hrs.
Annual Use (List Operations)
Planting
Fuel
Lubricants
Repairs & Maintenance
Tires, Supplies
Ownership Cost (Above)
Total Units Used
Cumulative Cost Data (Year 1 + Year

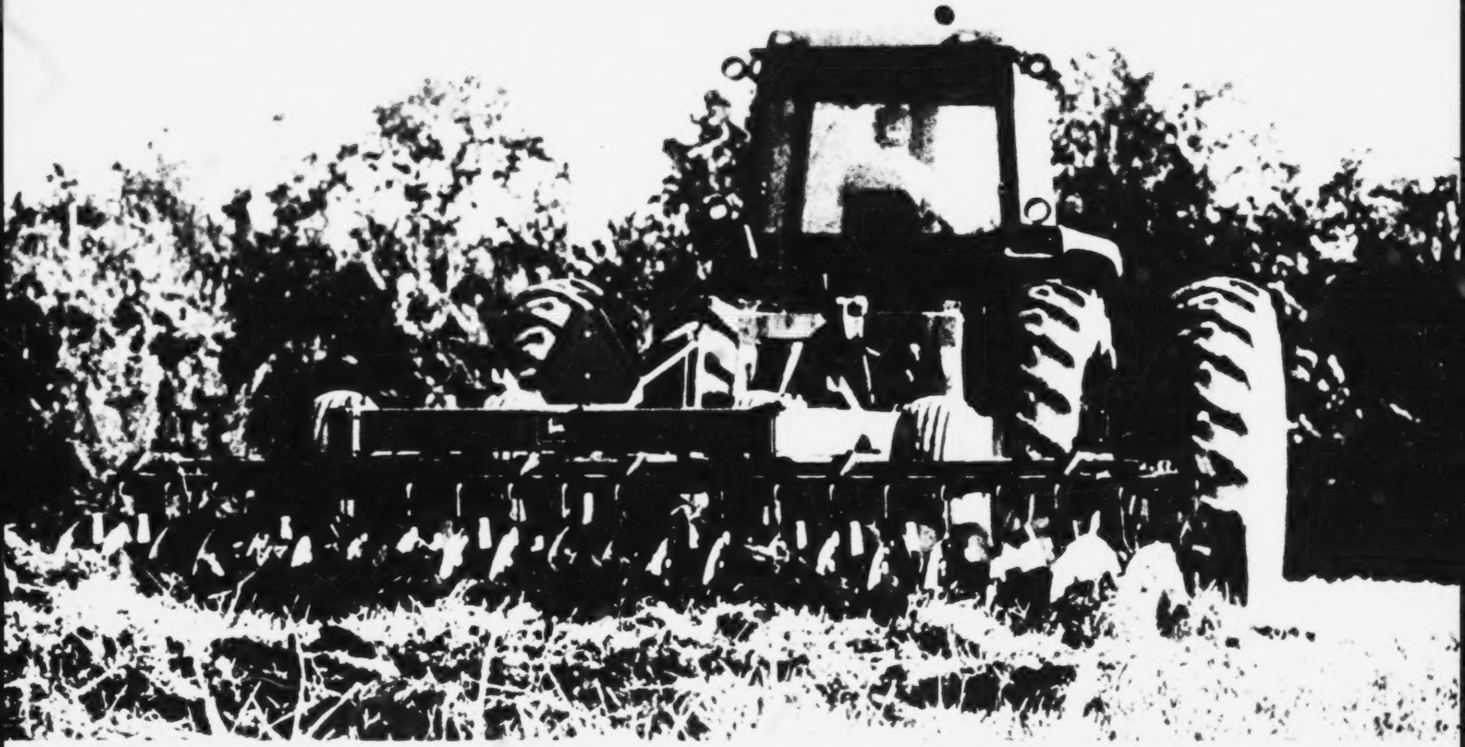


Fig. 4—Matching Machines And Power Units Is Another Important Management Decision

for making changes in machines and the machine-labor mix may become apparent due to efficiency and timeliness factors.

Timeliness is the *most* important factor to consider when considering machinery management techniques. In fact, a good "rule of thumb" when considering buying new machines with little cost difference is to purchase the machine that affords more timely operation.

Machinery management skills for making the best choice of the many options when trading because of machine age or to improve timeliness of operation include:

- Estimating machine capacity
- Matching machines and power units
- Estimating fuel, lubricant and repair costs
- Deciding when to trade
- Sizing machinery to farming operations
- Considering custom work
- Using leasing or renting

Let's review these decision-making skills and their potential impact on a machinery management program.

ESTIMATING MACHINE CAPACITY

In Chapter 2 you learned how to combine width, speed and field efficiency to accurately estimate capacity. This is an important point if machines are to be properly matched and fitted into available working time. It is also important not to be misled by the exceptionally good years or exceptionally bad years.

For example, suppose you want to combine 300 acres (122 ha) of wheat in 7 calendar days, and 40 hours of field time is what you can expect based on past records. You need 7.5 acres (3 hectares) per hour of capacity. If you drive at a speed of 4 miles per hour, how wide should the header be?

You can solve this problem with either the formulas or nomograph indicated in Chapter 2 and arrive at the answer of 22 feet (6.7 meters).

As a rule of thumb, multiply the width of a machine in feet times its speed in miles per hour, and the answer will be an approximate number of acres the machine will cover in a typical working day of approximately ten hours. Of course, this will not give as accurate an answer as the formulas and nomographs given in Chapter 2, but provides a guide for quick decisions.

MATCHING MACHINES AND POWER UNITS

Probably one of the most important machinery management decisions made is properly matching power units and machines. With large investments for tractor units and matching equipment, mistakes made in matching machines can be expensive (Fig. 4).

Having too much machine for the tractor is probably one of the worst and most unnecessary mistakes made. An oversize machine can overload and shorten the life of the tractor, resulting in excessive downtime and high repair bills.

This type of mistake means having a higher, unnecessary cost for the equipment because of unused capacity. Furthermore, if a tractor cannot pull the implements fast enough, the quality of the work may suffer.

Information in Chapter 4 covered determining the amount of available horsepower a tractor will have at the drawbar under various conditions and how equipment can be sized to end up with the proper field speed and best quality of work.

Carefully evaluating the different alternatives will result in the lowest cost per unit of work. Equipment will usually last from 25 to 50 percent longer if sized properly.

ESTIMATING FUEL, LUBRICANT AND REPAIR COSTS

Information was provided in Chapter 7 on how to estimate fuel and lubricant costs while Chapter 8 provided information on estimating repair costs and the importance of reliability. Chapter 9 combined these costs into a single cost estimate for any machine or tractor for varying conditions. By being able to make accurate cost estimates, you will be in a position to know when to trade and when to use a custom operator instead of buying machinery.

In today's farm management programs, it is a common practice to have a complete set of books indicating costs, gross income and net income to be expected from each phase of the farming operation. By accurately estimating costs you can predict the situation more accurately for each enterprise and avoid those mistakes which would indicate a profit when actually a loss occurred.

These detailed budgets are also important for evaluating different enterprises or different farming methods. If you are going to rent out equipment or do some custom work, it is important that you know exactly how much it costs to own and operate a machine.

Again, being able to make accurate cost estimates will permit correct decisions that can determine whether or not you make a profit.

DECIDING WHEN TO TRADE

A full complement of shiny, new equipment may be nice to operate and look at, but trading too often can result in increased fixed costs. On the other hand, trying to stretch the ownership period of your machinery too far will cause problems of reliability, lost field time and reduced crop yields. Timeliness of field operations is becoming more and more critical.

The best time to trade for most machinery is between one-half and three-fourths of its useful mechanical life. The more a machine is used per year, the more nearly you would trade at one-half life.

In sizing machines and tractors to fit farming operations, it is best not to plan on ownership longer than ten years for tractors and eight years for machines. In the case of new concepts of machines, a maximum life of approximately six years should be used.

SIZING MACHINERY TO YOUR FARMING OPERATION

In nearly every farming operation, heavy tillage usually determines how large a tractor is needed. By putting together several of the subjects in Section I on matching machinery, estimating machine capacity and matching the machines to the power units, it is possible to properly determine the size of the tractors and equipment needed (Fig. 5).

The best selection method is to single out the heavy tillage operations and the amount of time available to get all work done. From this starting point, determine how large the tractor and the machinery will need to be. It is also important to buy larger equipment if you are anticipating growth in future years, rather than having to trade in a few years when the size of field operations is increased.

CONSIDERING CUSTOM WORK

For sizable farming operations it sometimes pays to have access to custom operators for getting a crop out in time, even though the same type of machine may already be owned.

For the smaller-acreage farmers who want to own machinery but do not have enough acreage to justify ownership, extending the use of a machine through custom work is an excellent way to reduce costs.

In any case, apply all you have learned in this book in the way of estimating machine capacity, performance, field efficiency and accurate costs in order to estimate and set custom work costs.

USING LEASING OR RENTAL ARRANGEMENTS

As shown in Chapter 13, many farmers can benefit from owning their equipment rather than leasing or renting. However, over a period of several years' time, the individual situation may dictate exceptions to this statement.

Fig. 5—Heavy Tillage Usually Determines The Size Of A Tractor

In the case of leasing, access to a particularly good deal by a local dealer for a machine permits use of capital spent otherwise in the business. But remember that signing a lease agreement commits capital in the same way a loan does to buy the same piece of equipment.

Renting is sometimes used by operators who have specialty needs or can work out a deal with an implement dealer to have access to machines like tractors and tillage tools during critical operation periods. Whether you will actually use leasing or renting will also depend on your ability to keep the pencil sharp and carefully figure your own costs.

SUMMARY

This chapter reviews some of the highlights and more important concepts of machinery management discussed in this book. The end result of this book should be at least an increased awareness of the value of good machinery management and how it fits into the total farm management programs.

As stressed, timeliness has become one of the most critical factors in making machinery management decisions. It is only by keeping accurate records or obtaining good records of available working days, that timeliness factors can be determined for your specific area and situation.

Efficiency is another area where it is easy to gain more productivity at little or no extra cost. Up to ten percent more work can be accomplished on some farms by simply increasing field efficiency to a higher level.

CHAPTER QUIZ

1. Even if you use a computer to aid in machinery management decisions, why is it still important to understand the basics of machinery management?

2. What are the three reasons machinery management is being recognized as a more important factor in farm management?

3. What has become the most important factor in machinery management? Why?

4. In what area is it easiest to gain productivity with existing machinery?

15

Case Studies In Machinery Management

INTRODUCTION

Managing a farm or ranch business is a continuing process of learning, planning, evaluating, and decision-making. Each manager's goal must be to maximize returns to their business (Fig. 1).

Machinery management is an important part of farm and ranch business management. Only the cost for land exceeds the cost of owning and operating machinery. The case studies in this chapter will illustrate how decisions about machinery can affect the entire farm and ranch business program.

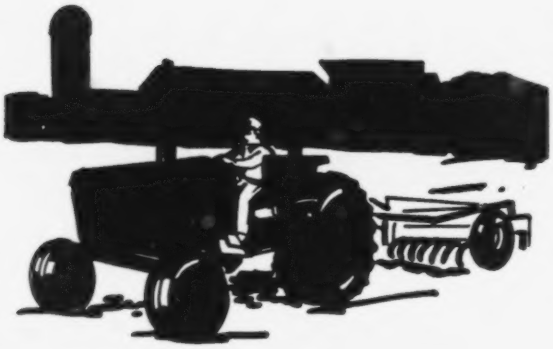


Fig. 1 — Only Land Costs Are Higher Than Machinery Costs

	4-Row System	8-Row System
Avg calendar days to plant	12	6.5
Avg working hours/day	4.1	4.1
Timeliness losses, acres of corn (Chapter 11,)	11	5.5
Average yield, bu/ac	141.5	146
Planter size	4 x 30 in	8 x 30 in
Planter capacity, ac/hr	4	7.5

The cost analysis of the two situations shows the economical benefit of their decision.

CASE STUDY — RECORD KEEPING

Jack and Sue Johnson use an extensive set of records in order to make their management decisions. A good example of this is the time when they decided to trade their four-row corn planter for an eight-row model.

The Johnson's have farmed their river bottom land in Eastern Iowa for ten years. They raise 200 acres of corn and 200 acres of soybeans. Corn yields are close to 150 bushels per acre, and soybean yield is consistently over 40 bushels per acre.

Record keeping has always been an important part of their business. Without this information, Jack and Sue would not have been able to cope with the frustrations of farming including the problems associated with the productive but unpredictable bottom land. After their first five years on the land, they found that corn yields were running slightly below their projections. Records further revealed that an average of 12 calendar days were required to complete corn planting due to the limited number of days when their bottom land was dry enough to work. From their records, they calculated that corn yields decreased at a rate of one percent per day after the optimum day.

Based on this information, the Johnson's decided to reduce planting time by increasing the capacity of their corn planter. By cutting their planting time in half, they justified the purchase of their new planter. The following analysis shows how they arrived at their decision.

	4-Row	8-Row
Cost of planter	$4,700	$10,000
Length of ownership, yrs	8	8
Avg fixed costs (Chapter 6)		
Per year, % of list price	13.45%	13.45%
Per year, total cost	$632	$1,345
Timeliness loss		
Acres (equivalent)	11	5.5
Bushels	1,650	825
Dollars @ $2.25/bu	$3,713	$1,856
Total costs (timeliness+fixed)	$4,345	$3,201
Advantage for new system (Fig. 3)		$1,144

NOTE: Operating costs were not included as they would be approximately the same for both operations.

Analysis: This is an example of the benefits that can be obtained from a good record keeping system. The increase in fixed costs per year from the larger planter is more than offset by increased production. Their detailed records give them confidence by showing that they can get an increase in income by increasing planting capacity. The fact that corn yields will decline after the optimum date for planting is well documented. In this case it is even more important because of frequent flooding of the fields. The extra capacity also benefits their soybean planting. Finally, there would even be a benefit to the harvest season since the corn would mature slightly earlier. In order to further reduce costs, the Johnsons wisely purchase an eight-row planter that requires the same harvesting system as their old four-row unit.

CASE STUDY — THE COST OF NEW MACHINERY

Jim Renner has participated in a record keeping service at his local lending institution for ten years (Fig. 2). He has been very pleased with the service, particularly since it provides the kind of information needed by his tax consultant. His record keeping service also provides a procedure for entering his machinery performance and cost data. For several years Jim didn't use this part of the system. He preferred to make machinery management decisions on his own. He liked to keep his equipment new and believed that frequent trading was necessary in order to take advantage of the investment tax credit.

His operation had been quite profitable in the earlier years so he could use all of the investment credit. When the farm economy took a turn for the worse, he was faced with a declining net income and knew that he needed to cut costs. But where? He started keeping more complete records on machinery performance, costs of repairs, maintenance and cost to trade. The record keeping service provided estimates on cost of ownership, based on a declining balance depreciation formula similar to the one in this text (Chapter 6).

Fig. 2 — Good Records Help You Make Management Decisions

After a few years of keeping more thorough records, Jim could see some ways to cut costs. The most serious problem that showed up from the records of the last few years was the difference between estimated and actual costs for the machinery. The record keeping service assumed an ownership period of 10 years for his machinery, however, his own records indicated that he was trading in intervals of 3 to 5 years for most of the major machines. The differences in actual and projected costs for his combine and tractors is shown below.

Actual costs exceed the estimated costs for the two tractors and the combine by a total of $5,796 a year before allowing for the investment tax credit. After allowing for the investment credit, the costs still exceeds estimates by $4,353 per year. Annual use is actually less than estimated. As a result, Jim starts using the machinery record portion of his record keeping service. He also decides not to trade as frequently as in the past. More effort will go into repairs and maintenance in order to maintain the reliability of his current machinery.

	100 hp Tractor	150 hp Tractor	Combine
Annual Use Hrs/Yr			
Estimated	600	500	150
Actual	550	450	125
Length of Ownership, Yrs			
Estimated	10	10	10
Actual	4	5	6
Cost, New	$38,000	$54,000	$80,000
Fixed Costs Plus Repairs Per year			
Estimated	$6,338	$8,451	$12,036
Actual	$8,256	$10,425	$13,940
Investment Credit, Pro-Rated, Annual			
Estimated	$380	$540	$1,000
Actual	$950	$1,080	$1,333

Analysis: A good record keeping system is essential when decisions must be made. Good records also are necessary in order to make sure your income tax forms are correctly filled out. With his data, Jim could determine exactly what tax credits he could claim.

The money loss shown in this example will be much higher if investment tax credits are not allowed. If Jim had looked at these estimates carefully in the past and kept accurate records on his machinery costs, then he would have realized the effect of early trading on fixed costs. More important, Jim's situation shows the attitude often adopted by managers when income is good and there is less pressure to cut costs. If you are serious about being a top manager, it is important to use records to know and understand all you can about your farm business all of the time.

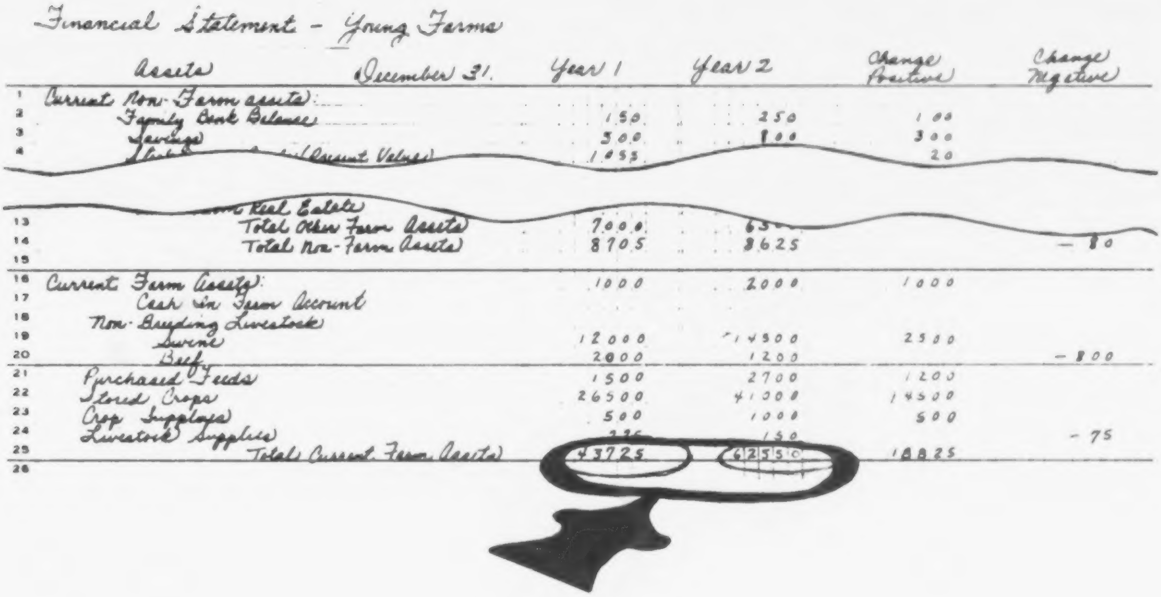
Fortunately, Jim understands the importance of complete records including those on his actual costs of owning and operating farm machinery. He knows that with the loss of the investment tax credit, longer ownership is going to be worth more than $5,000 a year. With longer ownership it also will pay to have a good maintenance and repair program in order to maintain the reliability and avoid breakdowns of his current machinery.

CASE STUDY — FINANCIAL ANALYSIS

A financial analysis is a process that is used to determine the health of the farm or ranch business (Fig. 3). The success of the farm manager often depends more on the use of a financial analysis than any other management tool. For this reason, financial statements must be considered as an integral part of farm and ranch management. A financial statement will do the following:

- Help obtain credit
- Determine net worth of the business and which way it is going
- Determine liquidity — the ability to convert assets to cash
- Determine solvency — measures the amount left after converting assets to cash and paying all debts
- Determine equity, particularly the ratio of debt to equity, another measure of solvency
- Determine borrowing power at a point in time

A financial analysis shows where you have been and where you are headed, financially. In other words, it can measure the success of the business.



Financial Statement - Young Farms

	Assets December 31.	Year 1	Year 2	Change Positive	Change Negative
1	Current Non-Farm Assets:				
2	Family Bank Balance	150	250	100	
3	Savings	500	800	300	
4	(Current Value)	1055			20
	Real Estate				
13	Total Other Farm Assets	7000	65		
14	Total Non-Farm Assets	8705	8625		− 80
15					
16	Current Farm Assets:	1000	2000	1000	
17	Cash in Farm Account				
18	Non-Breeding Livestock				
19	Swine	12000	14500	2500	
20	Beef	2000	1200		− 800
21	Purchased Feeds	1500	2700	1200	
22	Stored Crops	26500	41000	14500	
23	Crop Supplies	500	1000	500	
24	Livestock Supplies	225	150		− 75
25	Total Current Farm Assets	43725	62550	18825	
26					

Fig. 3 — Financial Statements Help You Determine The Health of Your Business

PEER PRESSURE

Rick Young is 27 years old and has been lucky to get an early start in farming on his own. He took over from his father when he was 19 years old. He is an only child, has been married for three years to Jane, and loves to farm.

At first, he made the usual mistakes of a young, eager farmer. He worked hard, learned from his experiences and soon gained a reputation for being a good farmer. He has a good mix of new and used equipment with plenty of capacity to get everything done on time. Within a few years time he has expanded his operation to 1500 acres, mainly as a tenant. It seems that everyone wants him for a tenant. Besides 400 acres of his parents' land, he bought 90 acres with a farmstead, including an old house.

By using soil tests, quality seed, and proper chemicals, Rick's yields slowly increased. His family has always been conservative and Rick again continues the tradition. Instead of building a new house, he and Jane remodel the old farmhouse on the land that they purchase. With the same attitude, Rick is always on the lookout for bargains in used equipment. He tries to keep his equipment inventory low in value but adequate to provide plenty of capacity in the field.

Rick does not belong to an outside record keeping service, but he has a filing system where he can retrieve any information necessary for tax purposes or for making decisions. Increasing yields coupled with shrewd marketing and low machinery costs means that he is in good shape financially. Other than loans for a storage bin and a combine, his only major debt is a mortgage on the 90 acres where the farmstead is located.

In the past, Rick has made most of his own decisions after consulting with family members. Today he is being influenced more and more by his neighbor Steve Sample. Steve is about his age and started farming about the same time. Steve is heavily in debt. He recently bought a new four-wheel-drive tractor and a new house. Steve convinces Rick that he also should get a four-wheel-drive tractor. He convinces Rick that it would save him time because of the added capacity. Rick likes the idea of more leisure time for he and Jane.

Rick first talks to his local dealer and finds that he can trade for the new tractor for $80,000 and his two older tractors. Rick next visits his lending institution. His lender, George Scott, is 60 years old. He has lived through the depression of the 30's and the depressed economic condition of the 80's. George says, "Rick, I have known your family for 40 years. I also know that you would qualify for the loan, but let's start with a financial statement just to see how you are doing." Rick works out the financial statement. He sees that his net worth has been steadily increasing. His cash flow is better than the average. Projections for the next two years show that he will be able to meet all operating costs and existing loan payments if prices will remain at the level of the past two years.

The new loan of $80,000 for six years would mean an annual payment of $18,000. George says "while the $80,000 loan would still keep your equity to debt ratio within allowable limits, you would be left without much borrowing power for emergencies. If you were 30 years older and your business stabilized, then I would recommend that you ask for the loan. It would make life easier, but it would do very little, if any, to increase your net income. You are still in a growth process and need to use your capital for productive assets. You also need a reserve for emergencies. If prices decline still further, you could be in serious trouble within two years."

The more George talks the more Rick realizes what he is trying to tell him. He really doesn't need the big tractor. It would only be used 400 hours a year and the cost per acre would be higher than necessary. As a result, Rick trades the oldest tractor, which is 12 years old and needs extensive transmission work, for a new 150 horsepower tractor. This is about half the cost of the four-wheel-drive tractor that he first thought that he needed. The table below shows why the decision to buy the smaller tractor kept Rick and Jane in a much better financial position.

Available Borrowing Power, Current	$90,000
After Trading For 4-Wh Drive	$10,000
After Trading For 2-Wh Drive	$50,000
Annual Loan Payments, 4-Wh Drive, 6 Yr Loan	$18,000
Annual Loan Payments, 2-Wh Drive, 6 Yr Loan	$9,000

Analysis: Rick's situation is typical. He starts conservatively and stays out of heavy debt. Then as time goes on and he gains confidence and experience, he feels that he must keep up with his neighbors. George's advice is sound and reaffirms the need for him to deal with his own situation and not be influenced by his neighbors. By trading for the smaller tractor and continuing to work longer hours, he saves $9,000 a year. He also maintains a better reserve in borrowing power for emergencies. The bottom line is the fact that the four-wheel-drive tractor would not increase income and may place Rick in a precarious financial position.

CASE STUDY — USING A BUDGET

A budget is a plan for spending or saving money. Budgets take time if they are done properly, but they are invaluable to the farm manager. There are several kinds of budgets with each having its place in the management of the farm business. A whole farm budget is a plan showing expenses and projected income for the entire farm, including all of the enterprises. An enterprise budget is the same but it is used for a single enterprise such as the production of cotton, wheat, cattle, or poultry. Sometimes a partial budget is used if only a portion of the projected income and expenses for an enterprise is needed (Fig. 4).

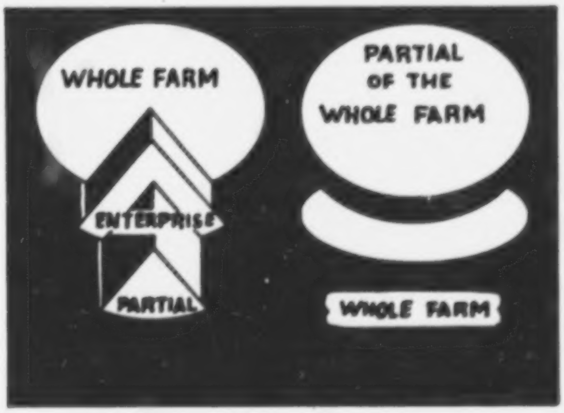


Fig. 4 — The Whole Farm Budget Can Be Divided Into Many Pieces

Budgets tell you if an enterprise is making a profit. Perhaps the greatest value in using budgets is to compare different plans or alternatives for an enterprise to determine which plan will show the greatest profit.

Dale Remington runs a large diversified farming operation in central Oklahoma. His operation includes cattle, hogs, wheat, cotton, and bermuda hay. His main source of income is from the cattle operation, which uses most of the bermuda hay produced on the farm.

He owns a conventional baler but uses custom hauling for his bermuda hay. he wants to continue bringing the bermuda hay program up to its productive potential, which will then allow for the expansion of the cattle operation.

Dale wants to look at an enterprise budget for using a loose hay stacking system instead of the conventional bale system. With the help of the local Extension Service he develops the enterprise budgets below, comparing the custom operation with owning his own loose hay stacking system.

The bermuda operation includes 100 acres that produces about 4.5 tons per acre.

ENTERPRISE BUDGETS

Operating Inputs	Conventional Bales	Own a Loose Hay Stacking System
Fertilizer	$38.60	$38.60
Custom Haul	47.60	------
Spray	2.60	2.60
Stand Establishment	8.00	8.00
Rent Fert. Spreader	1.25	1.25
Labor	10.35	12.98
Machinery Fuel,Lube Repairs	22.49	32.21
Misc.	17.14	10.95
Total Operating Costs/ac	$148.03	$106.59
Fixed Costs		
Machinery	$54.01	$62.95
Land	0.00	0.00
Total Fixed Costs/ac	$54.01	$62.95
Returns		
100 acres of bermuda,4.5 t/ac @ $50.00	$225.00	$225.00
Returns Above All Costs /ac	$26.96	$55.46

Increased Returns, 100 ac x($55.46-$22.96)=$3.250/yr

Analysis: This was a straightforward example of the use of budgets to help make a profitable management decision. The same approach could have been used to compare other alternatives, such as a big round bale system, along with the stacking wagon system. The key to success in using budgets is the accuracy of the inputs. It is much more difficult to accurately estimate machinery costs than other farm inputs such as feed, fertilizer, and chemicals. Again, the importance of using the information in this text along with other farm management resources is strongly encouraged.

CASE STUDY — CASH FLOW ANALYSIS

There are two kinds of cash flow analysis. One is a cash flow summary which is a financial history of business transactions over a given time period. A cash flow projection is a future plan for money transactions over a specific period of time. Cash flow planning has become an increasingly valuable tool for managers. It is used to help increase capital at specific times of the year.

Increased capital may also mean that operating costs increase. Failure to have cash to pay operating costs is the first step to financial failure.

Cash flow projections can help the manager make decisions by choosing from a set of alternatives. Such is the situation with the following case study.

Mike White and his wife Kathy have been operating a 360 acre farm. They want to rent more land; including the eighty acres of good farm land only two miles down the road.

The additional land also means additional equipment with the most critical item being the need for a larger tractor. Mike recently purchased a 100-hp tractor and must make payments of $6,250 year for four more years.

After carefully reviewing their cash flow projections they rule out the trade for a larger tractor. Their annual payments would go up by $7,500 a year and eliminate all of their remaining borrowing power. This leaves them with three alternatives.

- Buy a used tractor with approximately 100 hp
- Rent a 150-hp tractor for two months in the spring and one month in the fall
- Lease a new 100-hp tractor with an option to buy

Option 1. Buy a used tractor
Cost — $25,000 annual payments would be $6,000 a year.

Option 2. Rent a 150-hp tractor for two months in the spring and one month in the fall.
Cost — $1,250 per month for a total cost of $3750 per year.

Option 3. Lease-purchase
Cost — $7,500 per year for five years.

Analysis: Option 1 might be a good one if they can find a reliable used tractor that is not too old. Their cash flow also tells them that they cannot afford the risk of buying a used tractor and then having a major breakdown.

The lease purchase plan has a five-year commitment of $7,500 a year, which is little better than owning.

By renting the tractor they have adequate borrowing power when they need it most. They have more cash to use for the purchase of needed tillage tools. By renting, they keep their options open, including the possibility of making a trade for a new 150-hp tractor in a few years.

SUMMARY

Machinery management should not be separated from the total farm or ranch management system. The examples used in this chapter provide a brief look at the use of standard farm management procedures in making decisions involving farm machinery.

Learning to use these procedures is going to help you make decisions and increase the chances for achieving production and profit goals for your farm or ranch. By combining proper management procedures with your own accurate record keeping you will gain confidence in achieving financial and personal goals.

CHAPTER QUIZ

1. What is the first step to determining the financial status of a farm business?

2. What would you do if your neighbor tries to convince you that you need a bigger tractor in order to get your work done faster?

3. Which of the financial procedures discussed in this chapter would be the most difficult to accomplish?

4. What can you learn from a cash flow projection?

5. Which procedure would you use to compare a minimum tillage program to conventional tillage.

6. After reviewing what you have learned from this chapter, develop a list of the steps you can take to become a better farm manager?

APPENDIX

Fixed Costs and Repairs Tables

Calculator Problems

Suggested Reading

Weights and Measures

Index

Fixed Costs and Repairs Tables

TABLE 1

2- AND 4- WHEEL DRIVE TRACTORS

Useful life = 10,000 hours   Repair costs = $\$1{,}000 \times .9 \times .000631 \times (\%\ \text{life}^{1.6})$
Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

	(Age, Years)									
Hours of annual use	1	2	3	4	5	6	7	8	9	10
400	$1.176	$0.745	$0.598	$0.523	$0.475	$0.442	$0.418	$0.398	$0.382	$0.369
450	$1.047	$0.666	$0.536	$0.470	$0.429	$0.400	$0.379	$0.362	$0.349	$0.338
500	$0.945	$0.603	$0.487	$0.428	$0.392	$0.367	$0.349	$0.334	$0.323	$0.313
550	$0.861	$0.551	$0.447	$0.395	$0.362	$0.340	$0.324	$0.312	$0.302	$0.293
600	$0.792	$0.509	$0.414	$0.367	$0.338	$0.318	$0.304	$0.293	$0.285	$0.278
650	$0.733	$0.473	$0.386	$0.343	$0.317	$0.300	$0.287	$0.278	$0.271	$0.265
700	$0.683	$0.442	$0.363	$0.323	$0.300	$0.284	$0.273	$0.265	$0.259	$0.254
750	$0.639	$0.416	$0.342	$0.306	$0.285	$0.271	$0.262	$0.254	$0.249	$0.245
800	$0.601	$0.392	$0.325	$0.292	$0.272	$0.260	$0.251	$0.245	$0.241	$0.237
850	$0.568	$0.372	$0.309	$0.279	$0.261	$0.250	$0.243	$0.237	$0.234	$0.231
900	$0.538	$0.354	$0.296	$0.268	$0.252	$0.242	$0.235	$0.231	$0.228	$0.225
950	$0.511	$0.338	$0.284	$0.258	$0.243	$0.234	$0.229	$0.225	$0.222	$0.221
1,000	$0.488	$0.324	$0.273	$0.249	$0.236	$0.228	$0.223	$0.220	$0.218	$0.217
1,050	$0.466	$0.311	$0.263	$0.241	$0.229	$0.222	$0.218	$0.215	$0.214	*
1,100	$0.447	$0.300	$0.255	$0.234	$0.223	$0.217	$0.214	$0.212	$0.211	*
1,150	$0.429	$0.289	$0.247	$0.228	$0.218	$0.213	$0.210	$0.208	*	*
1,200	$0.413	$0.280	$0.240	$0.222	$0.213	$0.209	$0.206	$0.205	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 2

CRAWLERS

Useful life = 16,000 hours   Repair costs = $\$1{,}000 \text{ x } .8 \text{ x } .000631 \text{ X } (\% \text{ life}^{1.6})$
average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

Hours of annual use	(Age, Years) 1	2	3	4	5	6	7	8	9	10
500	$0.936	$0.589	$0.470	$0.408	$0.369	$0.342	$0.321	$0.304	$0.290	$0.278
600	$0.782	$0.494	$0.395	$0.344	$0.312	$0.290	$0.273	$0.259	$0.248	$0.239
700	$0.672	$0.426	$0.342	$0.299	$0.272	$0.253	$0.239	$0.228	$0.219	$0.212
800	$0.590	$0.375	$0.302	$0.265	$0.242	$0.226	$0.215	$0.205	$0.198	$0.191
900	$0.526	$0.336	$0.272	$0.239	$0.219	$0.206	$0.196	$0.188	$0.181	$0.176
1,000	$0.474	$0.304	$0.247	$0.219	$0.201	$0.189	$0.181	$0.174	$0.169	$0.165
1,100	$0.433	$0.279	$0.228	$0.202	$0.187	$0.176	$0.169	$0.163	$0.159	$0.155
1,200	$0.398	$0.258	$0.211	$0.188	$0.175	$0.166	$0.159	$0.154	$0.151	$0.148
1,300	$0.369	$0.240	$0.198	$0.177	$0.165	$0.157	$0.151	$0.147	$0.144	$0.142
1,400	$0.344	$0.225	$0.186	$0.167	$0.156	$0.149	$0.145	$0.141	$0.139	$0.137
1,500	$0.322	$0.212	$0.176	$0.159	$0.149	$0.143	$0.139	$0.136	$0.134	$0.133
1,600	$0.303	$0.200	$0.168	$0.152	$0.143	$0.138	$0.134	$0.132	$0.130	$0.129
1,700	$0.287	$0.190	$0.160	$0.146	$0.138	$0.133	$0.130	$0.128	$0.127	*
1,800	$0.272	$0.182	$0.153	$0.140	$0.133	$0.129	$0.127	$0.125	*	*
1,900	$0.259	$0.174	$0.148	$0.136	$0.129	$0.126	$0.124	$0.123	*	*
2,000	$0.247	$0.167	$0.142	$0.131	$0.126	$0.123	$0.121	$0.121	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 3

COMBINES

Useful life = 3,000 hours   Repair costs = \$1,000 x .7 x .000251 x $(\%\ \text{life}^{1.8})$

Average accumulated cost per hour per \$1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per \$1,000 of initial list price

	(Age, Years)									
Hours of annual use	1	2	3	4	5	6	7	8	9	10
25	$16.389	$10.913	$8.945	$7.863	$7.141	$6.604	$6.178	$5.822	$5.517	$5.249
50	$8.201	$5.467	$4.488	$3.950	$3.593	$3.329	$3.119	$2.944	$2.795	$2.664
75	$5.474	$3.656	$3.007	$2.653	$2.418	$2.246	$2.109	$1.996	$1.900	$1.816
100	$4.111	$2.753	$2.270	$2.008	$1.836	$1.710	$1.611	$1.530	$1.461	$1.401
125	$3.295	$2.213	$1.831	$1.625	$1.491	$1.394	$1.318	$1.256	$1.204	$1.159
150	$2.752	$1.854	$1.540	$1.372	$1.264	$1.186	$1.126	$1.078	$1.038	$1.003
175	$2.365	$1.600	$1.334	$1.194	$1.105	$1.041	$0.993	$0.955	$0.923	$0.897
200	$2.075	$1.410	$1.181	$1.062	$0.987	$0.935	$0.896	$0.865	$0.841	$0.821
225	$1.850	$1.263	$1.063	$0.961	$0.898	$0.855	$0.823	$0.799	$0.780	$0.765
250	$1.670	$1.146	$0.970	$0.882	$0.828	$0.792	$0.767	$0.748	$0.734	$0.723
275	$1.524	$1.051	$0.895	$0.818	$0.772	$0.743	$0.723	$0.709	$0.699	$0.692
300	$1.402	$0.973	$0.833	$0.766	$0.727	$0.704	$0.688	$0.678	$0.672	$0.668
325	$1.300	$0.907	$0.782	$0.723	$0.691	$0.672	$0.660	$0.654	$0.651	*
350	$1.212	$0.852	$0.739	$0.687	$0.660	$0.646	$0.638	$0.635	*	*
375	$1.136	$0.804	$0.702	$0.657	$0.635	$0.624	$0.620	$0.620	*	*
400	$1.071	$0.762	$0.670	$0.631	$0.614	$0.606	$0.605	*	*	*
425	$1.013	$0.726	$0.643	$0.610	$0.596	$0.592	$0.594	*	*	*
450	$0.961	$0.695	$0.619	$0.591	$0.581	$0.580	*	*	*	*
475	$0.916	$0.667	$0.599	$0.575	$0.568	$0.570	*	*	*	*
500	$0.875	$0.642	$0.581	$0.561	$0.558	$0.562	*	*	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 4

COTTON HARVESTERS, CORN HEADS, CORN PICKERS

Useful life = 2,000 hours   Repair costs = $\$1{,}000 \times .75 \times .000631 \times (\%\ \text{life}^{1.6})$

Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

	(Age, Years)									
Hours of annual use	1	2	3	4	5	6	7	8	9	10
25	$20.907	$12.900	$10.077	$8.560	$7.575	$6.862	$6.308	$5.859	$5.483	$5.160
50	$10.481	$6.492	$5.091	$4.343	$3.860	$3.511	$3.243	$3.025	$2.844	$2.689
75	$7.012	$4.366	$3.443	$2.953	$2.639	$2.414	$2.242	$2.104	$1.989	$1.892
100	$5.282	$3.309	$2.626	$2.267	$2.039	$1.878	$1.755	$1.658	$1.578	$1.510
125	$4.247	$2.680	$2.142	$1.863	$1.687	$1.565	$1.473	$1.400	$1.342	$1.293
150	$3.559	$2.263	$1.824	$1.598	$1.459	$1.363	$1.292	$1.237	$1.193	$1.158
175	$3.070	$1.969	$1.600	$1.414	$1.300	$1.224	$1.168	$1.126	$1.094	$1.068
200	$2.704	$1.750	$1.435	$1.279	$1.185	$1.124	$1.080	$1.049	$1.025	$1.007
225	$2.421	$1.582	$1.309	$1.176	$1.099	$1.050	$1.016	$0.993	*	*
250	$2.196	$1.449	$1.211	$1.097	$1.033	$0.994	$0.968	$0.952	*	*
275	$2.012	$1.342	$1.132	$1.035	$0.982	$0.951	$0.932	*	*	*
300	$1.860	$1.254	$1.068	$0.984	$0.941	$0.917	*	*	*	*
325	$1.732	$1.180	$1.015	$0.943	$0.908	$0.891	*	*	*	*
350	$1.623	$1.118	$0.971	$0.910	$0.882	*	*	*	*	*
375	$1.529	$1.065	$0.934	$0.882	$0.861	*	*	*	*	*
400	$1.448	$1.020	$0.903	$0.859	$0.844	*	*	*	*	*
425	$1.376	$0.981	$0.876	$0.840	*	*	*	*	*	*
450	$1.313	$0.947	$0.853	$0.824	*	*	*	*	*	*
475	$1.257	$0.917	$0.834	$0.811	*	*	*	*	*	*
500	$1.207	$0.890	$0.817	$0.800	*	*	*	*	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 5

PLANTERS, DRILLS

Useful life = 1,000 hours   Repair costs = $1,000 x .75 x .000631 x (% $\text{life}^{1.6}$)
Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

Hours of annual use	(Age, Years) 1	2	3	4	5	6	7	8	9	10
25	$20.962	$12.984	$10.183	$8.686	$7.719	$7.023	$6.485	$6.051	$5.688	$5.378
50	$10.564	$6.618	$5.252	$4.535	$4.078	$3.755	$3.510	$3.315	$3.155	$3.021
75	$7.119	$4.527	$3.648	$3.197	$2.918	$2.725	$2.583	$2.474	$2.386	$2.315
100	$5.408	$3.500	$2.870	$2.557	$2.371	$2.248	$2.161	$2.097	$2.050	$2.013
125	$4.391	$2.898	$2.421	$2.194	$2.067	$1.988	$1.937	$1.903	*	*
150	$3.720	$2.507	$2.135	$1.968	$1.882	$1.834	*	*	*	*
175	$3.246	$2.237	$1.942	$1.820	$1.764	*	*	*	*	*
200	$2.896	$2.040	$1.805	$1.718	$1.688	*	*	*	*	*
225	$2.626	$1.893	$1.706	$1.648	*	*	*	*	*	*
250	$2.414	$1.781	$1.634	$1.600	*	*	*	*	*	*
275	$2.244	$1.693	$1.580	*	*	*	*	*	*	*
300	$2.104	$1.624	$1.539	*	*	*	*	*	*	*
325	$1.988	$1.568	$1.510	*	*	*	*	*	*	*
350	$1.891	$1.524	*	*	*	*	*	*	*	*
375	$1.808	$1.488	*	*	*	*	*	*	*	*
400	$1.738	$1.460	*	*	*	*	*	*	*	*
425	$1.677	$1.437	*	*	*	*	*	*	*	*
450	$1.625	$1.419	*	*	*	*	*	*	*	*
475	$1.579	$1.404	*	*	*	*	*	*	*	*
500	$1.539	$1.393	*	*	*	*	*	*	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 6

MOWERS

Useful life = 1,000 hours   Repair costs = $\$1{,}000 \times 1.8 \times .00251 \times (\%\ \text{life}^{1.3})$

Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

	(Age, Years)									
Hours of annual use	1	2	3	4	5	6	7	8	9	10
25	$21.475	$13.591	$10.851	$9.399	$8.468	$7.800	$7.288	$6.875	$6.532	$6.239
50	$11.172	$7.331	$6.030	$5.359	$4.939	$4.645	$4.423	$4.249	$4.106	$3.987
75	$7.787	$5.304	$4.491	$4.086	$3.841	$3.676	$3.556	$3.465	$3.393	$3.334
100	$6.121	$4.325	$3.759	$3.491	$3.337	$3.239	$3.172	$3.123	$3.088	$3.062
125	$5.140	$3.759	$3.345	$3.161	$3.063	$3.006	$2.972	$2.952	*	*
150	$4.498	$3.397	$3.086	$2.959	$2.901	$2.873	*	*	*	*
175	$4.049	$3.150	$2.915	$2.830	$2.800	*	*	*	*	*
200	$3.720	$2.974	$2.796	$2.744	$2.737	*	*	*	*	*
225	$3.470	$2.844	$2.712	$2.687	*	*	*	*	*	*
250	$3.275	$2.747	$2.652	$2.648	*	*	*	*	*	*
275	$3.119	$2.672	$2.609	*	*	*	*	*	*	*
300	$2.993	$2.615	$2.578	*	*	*	*	*	*	*
325	$2.890	$2.570	$2.556	*	*	*	*	*	*	*
350	$2.804	$2.535	*	*	*	*	*	*	*	*
375	$2.732	$2.507	*	*	*	*	*	*	*	*
400	$2.671	$2.486	*	*	*	*	*	*	*	*
425	$2.620	$2.469	*	*	*	*	*	*	*	*
450	$2.576	$2.457	*	*	*	*	*	*	*	*
475	$2.538	$2.448	*	*	*	*	*	*	*	*
500	$2.505	$2.442	*	*	*	*	*	*	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 7

PLOWS, SWATHERS, BALERS, BALEWAGONS, STACKWAGONS, FORAGE HARVESTERS

Useful life = 2,000 hours   Repair costs = $1,000 x .8 x .00251 x (% life$^{1.3}$)

Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial list price

Hours of annual use	(Age, Years) 1	2	3	4	5	6	7	8	9	10
25	$20.987	$12.991	$10.174	$8.661	$7.678	$6.966	$6.414	$5.966	$5.589	$5.266
50	$10.572	$6.592	$5.196	$4.449	$3.966	$3.617	$3.348	$3.129	$2.946	$2.790
75	$7.109	$4.470	$3.549	$3.059	$2.743	$2.516	$2.341	$2.200	$2.082	$1.982
100	$5.383	$3.415	$2.732	$2.371	$2.140	$1.974	$1.847	$1.745	$1.660	$1.588
125	$4.350	$2.786	$2.247	$1.963	$1.783	$1.654	$1.556	$1.478	$1.413	$1.358
150	$3.664	$2.369	$1.926	$1.695	$1.548	$1.445	$1.366	$1.304	$1.252	$1.209
175	$3.175	$2.074	$1.700	$1.506	$1.384	$1.298	$1.234	$1.183	$1.141	$1.106
200	$2.810	$1.854	$1.532	$1.366	$1.263	$1.191	$1.137	$1.094	$1.060	$1.031
225	$2.528	$1.684	$1.402	$1.259	$1.170	$1.109	$1.063	$1.028	*	*
250	$2.302	$1.550	$1.300	$1.174	$1.098	$1.045	$1.006	$0.976	*	*
275	$2.119	$1.440	$1.218	$1.107	$1.039	$0.994	$0.961	*	*	*
300	$1.966	$1.350	$1.150	$1.051	$0.992	$0.952	*	*	*	*
325	$1.838	$1.274	$1.093	$1.005	$0.953	$0.918	*	*	*	*
350	$1.728	$1.210	$1.045	$0.966	$0.920	*	*	*	*	*
375	$1.634	$1.155	$1.005	$0.933	$0.892	*	*	*	*	*
400	$1.552	$1.107	$0.969	$0.905	$0.869	*	*	*	*	*
425	$1.479	$1.066	$0.939	$0.881	*	*	*	*	*	*
450	$1.415	$1.029	$0.912	$0.859	*	*	*	*	*	*
475	$1.359	$0.996	$0.889	$0.841	*	*	*	*	*	*
500	$1.308	$0.968	$0.868	$0.825	*	*	*	*	*	*

* No cost shown since total use is greater than expected life of the machine.

TABLE 8

DISKS, CHISELS, FIELD CULTIVATORS, OTHER SIMILAR TILLAGE EQUIPMENT

Useful life = 2,000 hours Repair costs = $\$1{,}000 \times .65 \times .000251 \times (\%\ \text{life}^{1.8})$
Average accumulated cost per hour per $1,000 list price (including fixed costs and repairs but does not include labor or fuel and lubricant costs). Figures shown in this table are average accumulated costs based on original ownership of the machine since it was purchased.

Cost per hour per $1,000 of initial cost

	(Age, Years)									
Hours of annual use	1	2	3	4	5	6	7	8	9	10
25	$20.890	$12.876	$10.048	$8.528	$7.539	$6.823	$6.268	$5.817	$5.438	$5.113
50	$10.457	$6.459	$5.053	$4.300	$3.813	$3.462	$3.191	$2.972	$2.789	$2.633
75	$6.983	$4.327	$3.398	$2.904	$2.586	$2.359	$2.185	$2.046	$1.930	$1.832
100	$5.250	$3.266	$2.577	$2.214	$1.983	$1.820	$1.696	$1.597	$1.517	$1.449
125	$4.211	$2.633	$2.090	$1.807	$1.629	$1.505	$1.412	$1.340	$1.281	$1.233
150	$3.521	$2.214	$1.769	$1.540	$1.399	$1.302	$1.231	$1.177	$1.134	$1.100
175	$3.029	$1.918	$1.543	$1.354	$1.240	$1.163	$1.108	$1.068	$1.037	$1.014
200	$2.661	$1.697	$1.377	$1.218	$1.125	$1.064	$1.022	$0.992	$0.971	$0.956
225	$2.377	$1.527	$1.250	$1.116	$1.039	$0.991	$0.960	$0.939	*	*
250	$2.150	$1.393	$1.151	$1.036	$0.973	$0.936	$0.914	$0.901	*	*
275	$1.965	$1.285	$1.071	$0.974	$0.923	$0.895	$0.881	*	*	*
300	$1.811	$1.196	$1.007	$0.924	$0.883	$0.864	*	*	*	*
325	$1.682	$1.121	$0.954	$0.884	$0.852	$0.840	*	*	*	*
350	$1.572	$1.059	$0.910	$0.851	$0.828	*	*	*	*	*
375	$1.477	$1.005	$0.873	$0.825	$0.809	*	*	*	*	*
400	$1.395	$0.960	$0.842	$0.803	$0.794	*	*	*	*	*
425	$1.322	$0.920	$0.816	$0.785	*	*	*	*	*	*
450	$1.258	$0.886	$0.794	$0.771	*	*	*	*	*	*
475	$1.202	$0.856	$0.775	$0.759	*	*	*	*	*	*
500	$1.151	$0.829	$0.759	$0.750	*	*	*	*	*	*

* No cost shown since total use is greater than expected life of the machine. RaC2 border=2 RaC3

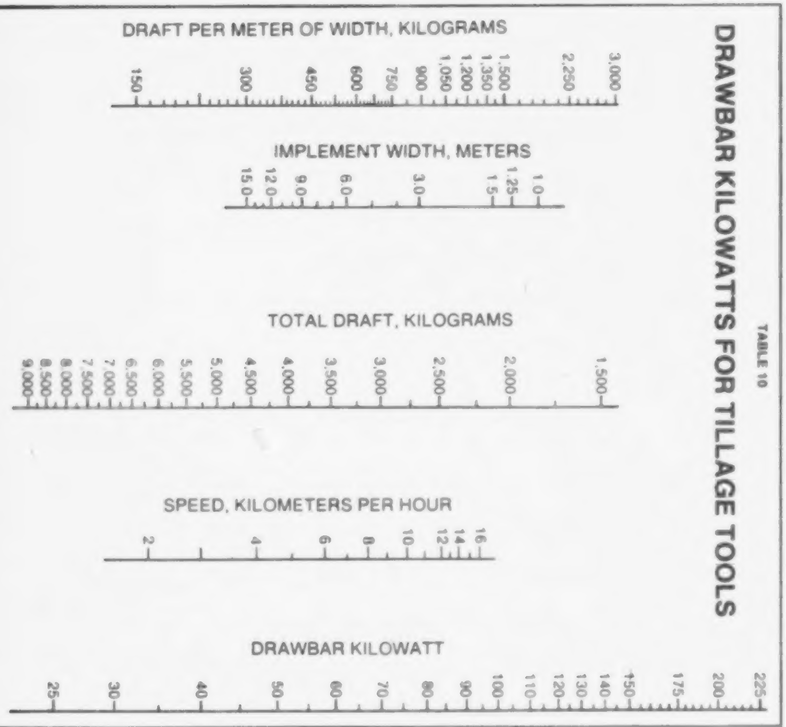


TABLE 10

DRAWBAR KILOWATTS FOR TILLAGE TOOLS

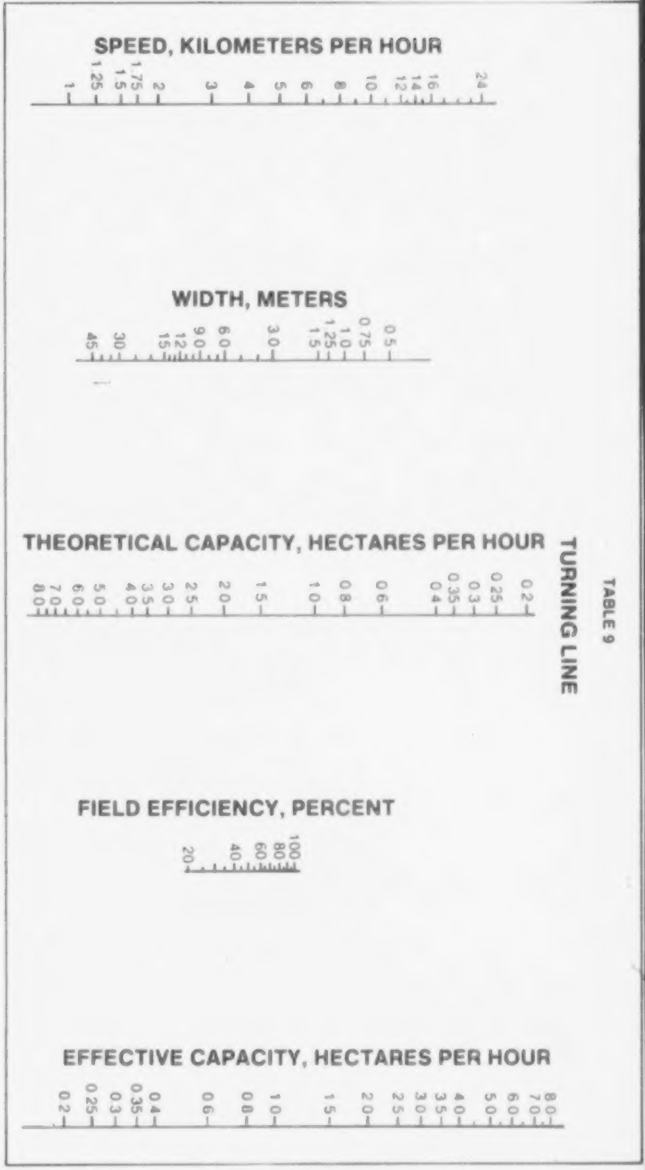


TABLE 9

TABLE 11

SOIL RESISTANCE

Operation	Kilonewtons of Draft/ Meter of Width	Typical Speed, km/h	Drawbar Kilowatt per Meter of Width
PLOWING (20-cm DEEP)			
Gumbo	18.23	6.4	32.5
Clay	15.31	6.4	27.3
Loam	13.86	7.2	27.8
Sandy Loam	10.21	8.0	22.7
Sand	5.1	8.0	11.5
CHISEL PLOWING (20-cm DEEP)			
Hard, Dry	11.67	6.4	20.7
Medium Clay Loam, Good Moisture	7.29	8.0	16.3
Sandy, Sandy Loam	2.92	9.7	7.8
FIELD CULTIVATOR			
Heavy Clay Soils or Dry and Hard Conditions	9.48	6.4	16.8
Clay Loam	6.56	8.0	14.6
Sandy Loam	4.37	8.0	9.8
Sand	2.19	9.7	5.9
TANDEM DISK HARROW			
Heavy Draft	4.37	6.4	7.8
Medium Draft	2.92	8.0	6.6
Light Draft	1.46	9.7	3.9
OFFSET OR HEAVY TANDEM DISK			
Heavy Draft	5.83	6.4	10.5
Medium Draft	4.74	8.0	10.5
Light Draft	3.65	9.7	9.8
ONE-WAY DISK			
Heavy Draft	5.83	6.4	10.5
Medium Draft	4.37	8.0	9.8
Light Draft	2.92	9.7	7.8

TABLE 12

COMPARING TILLAGE METHODS

Compare:	SYSTEM 1	SYSTEM 2
Operation	Conventional Tillage liters per hectare	Reduced Tillage liters per hectare
Disk stalks	4.21	4.21
Plow	15.71 (chisel)	10.29
Disk	6.08	—
Disk	6.08	—
Pre-emergence spray	0.94	0.94
Field Cultimulcher	5.61	5.61
Plant	4.68	3.74
Cultivate	4.21	4.21
Combine	14.96	14.96
TOTAL	62.46	43.95

TABLE 13

AVERAGE FUEL CONSUMPTION AND FUEL WEIGHT FOR DIFFERENT TYPES OF TRACTOR ENGINES

Engine (Fuel Type)	Average Fuel Consumption (Liters Per Hour Per Maximum PTO kW)	Typical Kilograms Per Liter
Gasoline	**0.345**	**0.73**
Diesel	**0.223**	**0.82**
LP-Gas	**0.406**	**0.50-0.53**

TABLE 14

AVERAGE ENERGY AND FUEL REQUIREMENTS

Operation	Energy Required, PTO kW-Hrs. Per Ha	Liters per Hectare Gaso-line	Diesel	LP-Gas
Shred stalks	19.3	9.3	6.7	11.2
Plow 8-inches deep	44.9	22	15.7	26.4
Heavy offset disk	25.4	12.4	8.9	15
Chisel plow	29.5	14.4	10.3	17.3
Tandem disk, stalks	11.0	5.9	4.2	7.1
Tandem disk, chiseled	12.7	7.2	5.1	8.6
Tandem disk, plowed	17.3	8.5	6.1	10.2
Field cultivate	14.7	7.9	5.6	9.4
Spring-tooth harrow	9.6	5.2	3.7	6.3
Spike-tooth harrow	6.3	3.9	2.8	4.7
Rod weeder	7.4	3.9	2.8	4.7
Sweep plow	16.0	7.9	5.6	9.4
Cultivate row crops	11.0	5.9	4.2	7.1
Rolling cultivator	7.2	4.6	3.3	5.5
Rotary hoe	5.2	3.3	2.3	3.9
Anhydrous applicator	17.3	8.5	6.1	10.2
Planting row crops	12.3	6.5	4.7	7.9
No-till planter	7.2	4.6	3.3	5.5
Till plant (with sweep)	8.3	5.2	3.7	6.3
Grain drill	8.7	4.6	3.3	5.5
Combine (small grains)	20.3	13.1	9.3	15.7
Combine, beans	22.1	14.4	10.3	17.3
Combine, corn and grain sorghum	32.4	20.9	15	25.1
Corn picker	23.2	15	10.7	18
Mower (cutterbar)	6.4	4.6	3.3	5.5
Mower conditioner	13.3	7.9	5.6	9.4
Swather	12.2	7.2	5.1	8.6
Rake, single	4.6	3.3	2.3	3.9
Rake, tandem	2.8	2	1.4	2.3
Baler	9.2	5.9	4.2	7.1
Stack wagon	11.0	6.5	4.7	7.9
Sprayer	1.8	1.3	0.9	1.6
Rotary mower	17.6	10.5	7.5	12.5
Haul small grains	11.0	7.9	5.6	9.4
Grain drying	154.6	78.5	56	94.2
Forage harvester, green forage	22.8	12.4	8.9	15
Forage harvester, haylage	30.0	16.4	11.7	19.6
Forage harvester, corn silage	86.0	47.1	33.6	56.5
Forage blower, green forage	8.5	4.6	3.3	5.5
Forage blower, haylage	6.1	3.3	2.3	3.9
Forage blower, corn silage	33.5	18.3	13.1	22
Forage blower, high-moisture ear corn	10.9	5.9	4.2	7.1

TABLE 15

AVERAGE FIXED AND REPAIR COSTS PER KILOWATT HOUR

New Cost Per kW	Annual Tractor Use, Hours Per Year 400	600	800	1,000	1,200
$400	$0.148	$0.117	$0.104	$0.094	$0.089
$470	$0.173	$0.138	$0.122	$0.111	$0.104
$535	$0.197	$0.157	$0.139	$0.126	$0.119

TABLE 16

SAMPLE HOURLY COST PER KILOWATT

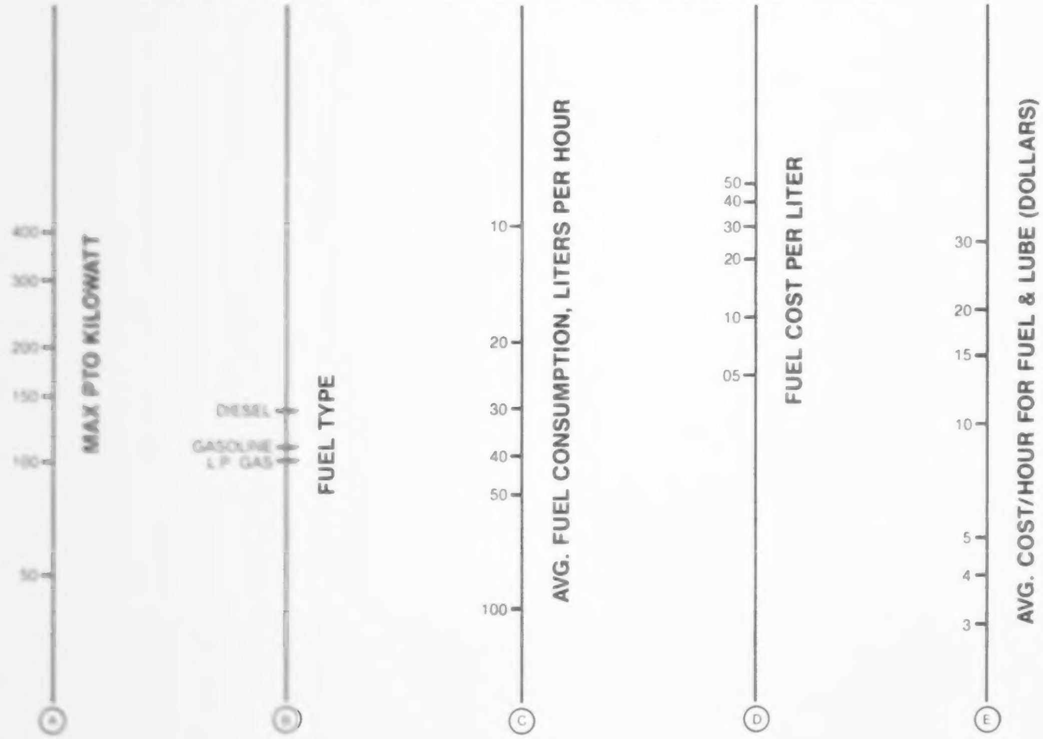
$35,000, 75-kW TRACTOR

	Annual Use, Hours				
	400	600	800	1,000	1,200
Cost to Own	$0.172	$0.137	$0.121	$0.110	$0.104
3-year lease*	$0.308	$0.222	$0.180	$0.154	$0.138
4-year lease*	$0.288	$0.205	$0.166	$0.143	$0.129
5-year lease*	$0.263	$0.189	$0.154	$0.135	$0.123

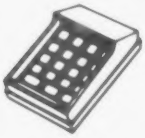
*Lease cost includes annual lease costs plus repairs, taxes and insurance. Cost prorated over life of tractor.

TABLE 17

NOMOGRAPH FOR ESTIMATING FUEL AND LUBRICANT COSTS



Calculator Problems



The problems presented in this section are problems selected throughout the book and marked with the above symbol. These problems are presented a second time here with simple steps provided on how to solve the problem using a calculator.

This section basically reviews problems and provides practice with a calculator. Using a calculator of any type can greatly speed up the process of making machinery management decisions.

Because some calculators differ in operation, read the owner's manual carefully for correct usage. Some types of calculators may not use the same entry system used in this section, but instructions in this section can be easily adapted.

CHAPTER 2

PAGE 11

Speed times width equals field capacity.

$$\frac{300\ \text{feet}}{\text{minute}} \times \frac{60\ \text{minutes}}{1\ \text{hour}} \times 20\ \text{feet} \times \frac{1\ \text{acre}}{43{,}560\ \text{ft.}^2}$$

ENTER 300
ENTER ×
ENTER 60
ENTER ×
ENTER 20
ENTER ÷
ENTER 43,560
ENTER =
ANSWER 8.26 acres per hour

PAGE 14

$$\text{Speed, mph} = \frac{2{,}600\ \text{feet}}{5.4\ \text{minutes} \times 88}$$

ENTER 2,600
ENTER ÷
ENTER 5.4
ENTER ÷
ENTER 88
ENTER =
ANSWER 5.47 mph

PAGE 17

$$\text{Theoretical capacity} = \frac{369{,}600}{43{,}560}$$

ENTER 369,600
ENTER ÷
ENTER 43,560
ENTER =
ANSWER 8.48 acres per hour

PAGE 17

Theoretical capacity, acres per hour

$$= \frac{\text{speed, mph} \times \text{width, feet}}{8.25}$$

Speed = 5 mph
Width = 14 feet

$$\text{Theoretical capacity} = \frac{5 \times 14}{8.25}$$

ENTER 5
ENTER ×
ENTER 14
ENTER ÷
ENTER 8.25
ENTER =
ANSWER 8.48 acres per hour

CHAPTER 4

PAGE 31

Theoretical field capacity

$$\text{TFC} = \frac{\text{width} \times \text{speed}}{8.25}$$

$$\text{TFC} = \frac{6.67\ \text{feet} \times 4.4\ \text{mph}}{8.25}$$

ENTER 6.67
ENTER ×
ENTER 4.4
ENTER ÷
ENTER 8.25
ENTER =
ANSWER 3.56 acres per hour

$$\text{EFC} = \text{TFC} \times \frac{\text{field efficiency}}{100}$$

$$\text{EFC} = 3.56\ \text{acres per hour} \times \frac{85}{100}$$

ENTER 3.56
ENTER ×
ENTER 85
ENTER ÷
ENTER 100
ENTER =
ANSWER 3.03 acres per hour

PAGE 32

$$\text{TFC} = \frac{14 \times 3.6}{8.25}$$

ENTER 14
ENTER ×
ENTER 3.6
ENTER ÷
ENTER 8.25

ENTER =
ANSWER 6.1 acres per hour

$$EFC = \frac{22 \text{ tons}}{\text{hour}} \times \frac{70}{100}$$

ENTER 22
ENTER ×
ENTER 70
ENTER ÷
ENTER 100
ENTER =
ANSWER 15.40 tons per hour

$$EFC = \frac{\text{width} \times \text{speed} \times \text{field efficiency}}{8.25}$$

ENTER 6
ENTER ×
ENTER 30
ENTER ÷
ENTER 12
ENTER =
ANSWER 15 feet
(Leave the answer of 15 feet in calculator)
ENTER ×
ENTER 3.2
ENTER ÷
ENTER 8.25
ENTER ×
ENTER 70
ENTER ÷
ENTER 100
ENTER =
ANSWER 4.07 acres per hour

PAGE 33

$$EFC = \frac{\text{width, feet} \times 5 \text{ mph}}{8.25} \times \frac{\text{field efficiency, percent}}{100}$$

$$EFC = \frac{\frac{6 \times 30}{12} \times 4.5 \text{ mph}}{8.24} \times \frac{60}{100}$$

ENTER 6
ENTER ×
ENTER 30
ENTER ÷
ENTER 12
ENTER =
Width is 15.0 feet
ENTER ×
ENTER 4.5
ENTER ÷
ENTER 8.25
ENTER =
TFC is 8.2 acres per hour
ENTER ×
ENTER 60
ENTER ÷
ENTER 100
ENTER =
EFC is 4.9 acres per hour

PAGE 36

$$\text{Width} = \frac{7.0 \times 8.25}{5 \times 0.65}$$

ENTER 7.0
ENTER ×
ENTER 8.25
ENTER ÷
ENTER 5
ENTER ÷
ENTER 0.65
ENTER =
ANSWER 17.77 feet, or for the answer in inches:
ENTER ×
ENTER 12
ENTER =
ANSWER 213 inches

CHAPTER 5

PAGE 42

$$\text{Drawbar Horsepower} = \frac{\text{force, pounds} \times \text{speed, mph}}{375}$$

Force = 2,500 pounds, speed = 5 mph

$$\text{Horsepower} = \frac{2{,}500 \times 5}{375}$$

ENTER 2,500
ENTER ×
ENTER 5
ENTER ÷

ENTER 375

ENTER =

ANSWER 33.3 horsepower

PAGE 44

$$\text{Speed} = \frac{\text{drawbar horsepower} \times 375}{\text{draft, pounds}}$$

Draft = 5,000 pounds

Horsepower = 65

ENTER 65

ENTER ×

ENTER 375

ENTER ÷

ENTER 5,000

ENTER =

ANSWER 4.87 mph

$$\text{Draft} = \frac{\text{hp} \times 375}{\text{speed, mph}}$$

Horsepower = 130

Speed = 6

ENTER 130

ENTER ×

ENTER 375

ENTER ÷

ENTER 4.5

ENTER =

ANSWER 8,125 pounds

PAGE 50

$$\text{Width} = \frac{\text{usable drawbar horsepower} \times 375}{\text{speed, mph} \times \text{draft, per foot}}$$

Usable drawbar horsepower = 97.15

Speed = 5 mph

Draft, per foot = 400 lbs.

ENTER 97.15

ENTER ×

ENTER 375

ENTER ÷

ENTER 5

ENTER ÷

ENTER 400

ENTER =

ANSWER 18.22 feet

PAGE 51

$$\text{Width} = \frac{8.25 \times \text{capacity}}{\text{speed}} \times \frac{100}{\text{efficiency}}$$

Capacity = 5.24 acres per hour

Speed = 4.5

Efficiency = 80 percent

ENTER 8.25

ENTER ×

ENTER 5.24

ENTER ÷

ENTER 4.5

ENTER ×

ENTER 100

ENTER ÷

ENTER 80

ENTER =

ANSWER 12 feet or 144 inches

CHAPTER 6

PAGE 62

$\text{RV} = \text{cost} \times 0.68 \times 0.92^3$

Cost = $36,000

ENTER 36,000

ENTER ×

ENTER 0.68

ENTER ×

ENTER 0.92

ENTER =

If calculator has a constant multiplier, enter the equal sign twice more.

ANSWER $19,062

If calculator does not have a constant multiplier,

ENTER ×

ENTER 0.92

ENTER =

ENTER ×

ENTER 0.92

ENTER =

ANSWER $19,062

CHAPTER 7

PAGE 74

Average fuel consumption = 60 × 0.068

ENTER 60

ENTER ×

ENTER 0.068

ENTER =

ANSWER 4.08 gallons per hour

PAGE 75

4.08 × 1.00

ENTER 4.08

ENTER ×

ENTER 1.00

ENTER =

ANSWER $4.08 per hour

PAGE 77

Estimating fuel and lubricant costs

Fuel and lubricant costs can be estimated as follows (for diesel tractor)

Horsepower x 0.044 x cost per gallon x 1.10, or

150 x 0.044 x $1.00 x 1.10

ENTER 150

ENTER X

ENTER .044

ENTER X

ENTER 1.00

ENTER X

ENTER 1.10

ENTER =

ANSWER $7.26

CHAPTER 9

PAGE 95

Estimating fixed costs plus repairs

$30,000 divided by $1,000 X .392

ENTER 30000

ENTER ÷

ENTER 1000

ENTER X

ENTER .392

ENTER =

ANSWER $11.76

2,500 X 411.76

ENTER 2500

ENTER X

ENTER $11.76

ENTER =

ANSWER $29,400

PAGE 96

Estimating fixed costs plus repairs

2,500 × $17.71

ENTER 2,500

ENTER ×

ENTER $17.71

ENTER =

ANSWER $44,275

CHAPTER 11

PAGE 116

Width $= \frac{2.88 \times 8.25}{4.5 \times .8}$

ENTER 2.88

ENTER ×

ENTER 8.25

ENTER ÷

ENTER 4.5

ENTER ÷

ENTER .8

ENTER =

ANSWER 6.6 feet

Drawbar horsepower $= \frac{5{,}280 \times 4.5}{375}$

ENTER 5,280

ENTER ×

ENTER 4.5

ENTER ÷

ENTER 375

ENTER =

ANSWER 63.4 horsepower

PAGE 117

Fuel and lubricant cost

$4.40 + (.10 X $4.40)

Hint: Multiply .10 X 4.40 first

ENTER	.10
ENTER	X
ENTER	4.40
ENTER	+
ENTER	4.40
ENTER	=
ANSWER	$4.84

USING COMPUTERS IN MACHINERY MANAGEMENT

This section will show how most of the important formulas in this book can be set up and used in a computer program to solve machinery management problems. Examples from the text will show how the formulas can be used in either "Basic" program language or in "Spreadsheets".

In most cases the computer symbols are those most commonly used in all program languages. If you have copied the example program accurately and it still doesn't work, check your manual to see if uses a different symbol or procedure is required.

The first example is a short procedure using BASIC.

Most computer programs use the following symbols for the common mathematical procedures:

+ Add   - Subtract   / divide   * Multiply ^ Raise to a power

Chapter 2 MEASURING MACHINE CAPACITY

Speed check, using example on page 14

Formula

Speed, miles per hour= distance, feet / (time, minutes * 88)

It is desirable to use single letters or at least, a small number of letters in the formulas.

Let S=speed, miles per hour;T=time, in minutes;D=distance, feet

The formula now is S=D/(T*88)

Example, from page 14   D=2,600 T=5.4

Type PRINT 2600/(5.4*88) and hit Enter

```
PRINT 2600/(5.4*88)

ENTER
```

The computer will print the answer 5.47138

This procedure simply uses the computer as a calculator

The following program sets up the same problem in a different way.

```
10 D= 2600
20 T=5.4
30 S=D/(T*88)
40 PRINT S
RUN
 5.47138
```

Check your manual on BASIC. There will be a procedure for rounding the number to give the desired number of places after the decimal

CHAPTER 4 DETERMINING MACHINE CAPACITY

An important part of this chapter is the formula for determining capacity of a given machine. The same formula can also be used to determine width, speed, or field efficiency if the other three factors are known. The formulas would be as follows:

Let S=speed, mph; W=width, feet; E=field efficiency, percent;

C=capacity, acres per hour

The formulas for C,S,W AND E are as follows:

C=(S*W*E/100)/8.25   S=(C*8.25)/(W*E/100)

W=(C*8.25)/(S*E/100)   E=(C*8.25)/(S*W/100)

Example, page 32   W=15; S=3.2; E=70

```
10 S=3.2
20 W=15
30 E=70
40 C=(S*W*E/100)/8.25
50 PRINT "The capacity is";C;"acres per hour"
RUN

The capacity is 4.07 acres per hour
```

The print statement gives the answer as a sentence

To show how the other formulas work, use the example on page 35

```
10 S=5.0:E=80:C=6
20 W=(C*8.25)/(S*E/100)
30 PRINT USING "The needed width, feet is ##.#";W
RUN

The needed width, feet is 12.4
```

This time we have introduced a different print statement to format the answer rounded to one place after the decimal. Also note that S,W and E were entered on the same line by separating each one with a colon.

In setting up problems that you want to try several times with various entries, use the example on page 36, and the following program in Basic

Let D=Days available; H= Average hours per day

S=Speed; A=Acres; E=Field efficiency; W=Width; C=Capacity ac/hr

```
10 INPUT "How many days are available";D
20 INPUT "Average number of hours per day";H
30 INPUT "Average speed";S
40 INPUT "How many acres to be worked";A
50 INPUT "What is the field efficiency";E
60 C=A/(H*D)
70 W=(C*8.25)/(S*E/100)
80 PRINT
90 PRINT USING "Needed capacity, acres hour is ##.#";C
100 PRINT
110 PRINT USING "Needed width, feet is ##.#";W
RUN
How many days are available? 10
Average number of hours per day? 4
Average speed, miles per hour? 5.0
How many acres to be worked? 280
What is the field efficiency, percent? 65

Needed capacity, acres per hour is 7.0

Needed width, feet is 17.8
```

The advantage of this program is the speed with you can change the answers by re-running the program and using different acres, speed, efficiency, etc. The INPUT statements will list the questions one at a time.

CHAPTER 5 ESTIMATING POWER REQUIREMENTS

The formula on page 42 may be used several different ways. In order to use the formula, you must know three of the following; speed in miles per hour, width in feet, draft in pounds per foot, and drawbar horsepower.

The formula is Horsepower=(force,pounds * speed, mph)/375

Force in pounds is (width, feet * draft, pounds per foot)

The following formulas can be used either in basic or in a spreadsheet.

W= width,ft; S=speed,mph; D=draft, lbs per foot; HP=drawbar hp

HP=(S*W*D)/375; S=(HP*375)/(W*D); W=(HP*375)/(S*D);

D=(HP*375)/(S*W)

Example: To solve for width in the problem on page 44 use the following basic program: Steps 1 and 2 have been combined.

```
10 HP=130
20 S=6
30 D=280
40 W=(HP*375)/(S*D)
50 PRINT USING "Implement width, feet is ##.#";W
RUN
Implement width, feet is 29.0
```

To solve for horsepower as shown in the text and in Fig. 13 on page 47 use the following:

```
10 S=4
20 D=400
30 W= 16
40 HP=(S*W*D)/375
50 PRINT Using "Required horsepower would be ###.";HP
RUN
Required horsepower would be 68.
```

CHAPTER 6 ESTIMATING FIXED COSTS

Examples will show both basic programs and a spreadsheet.

Table 4 on page 62 lists the estimated remaining value for tractors, combines and all other machines. The following program in basic will calculate the estimated remaining value of any machine of any age if the list price is known.

The formula for estimating remaining value at any age for any machine was adapted from pages 61 and 62 in the text.

```
RV= (List price * RO * (RA^Y))    RV= Remaining value
RO=.6 for tractors, .67 for combines and .56 for all others
RA=.935 for tractors, .92 for combines and .9 for all others
```

```
10 REM Code number:tractors=1,combines=2, all others=3
20 INPUT "What is the name of the machine";A$
30 INPUT "What is the code number";CN
40 INPUT "What was the list price";LP
50 INPUT "What is the age of the machine";Y
60 IF CN=1 GOTO 90
70 IF CN=2 GOTO 110
80 IF CN=3 GOTO 130
90 RO=.6:RA=.935
100 GOTO 150
110 RO=.67:RA=.92
120 GOTO 150
130 RO=.56:RA=.9
140 GOTO 150
150 RV=LP*RO*(RA^Y)
160 PRINT
170 PRINT "When the";A$;" is ";Y;"years old"
180 PRINT USING "The remaining value will be $##,###.";RV
Ok
RUN
What is the name of the machine? Tractor
What is the code number? 1
What was the list price? 36000
What is the age of the machine? 3

When the tractor is 3 years old
The remaining value will be $17,656.
```

The 10 REM statement is a non functioning statement to provide information or data that might be needed for the program.

USING THE SPREADSHEET

A spreadsheet may also be used to set up a table of remaining values for a specific machine. The following example shows one way this can be done.

Spreadsheets use alphabetical letters for columns and numbers for rows, providing coordinates for each "cell". Data and other information is entered into these cells from which large tables of information, such as remaining values, can be developed.

The following example shows how a spreadsheet can be used to develop remaining values and depreciation.

The Remaining Value formula is:

RO and RA are the two constants listed earlier. The same formula set up for use by a computer would be:

```
RV=List Price*RO*(RA^Y)
```

The remaining value for the $36,000 tractor when it is one year old is shown in cell C18 and was determined as follows:

```
(+$C$11*$C$13*($C$14^$A18))
```

List price was entered in cell C11, RO in C13, RA in C14 and Y in A18.

In this particular program the $ sign in front of the column or row "freezes" the location so it can be used by the copy or replicate command. Normally, a set of numbers are determined in this manner to save repeatedly entering the same formula every time.

The total depreciation formula would be (Actual cost minus remaining value), or C12-C18 for the first year.

Note that remaining value after 3 years is $17,656, the same as determined earlier in the Basic program.

Once the table is set up in the spreadsheet other information such as hourly depreciation can be quickly developed.

An important advantage of the spreadsheet is the ease with which data can be generated for different situations. For example, remaining values and depreciation can be determined for any machine simply by changing the data entered in cells C11, C12, C13 and C14

```
         A         B         C         D         E         F

 1   REMAINING VALUE OF TRACTORS AND MACHINERY
 2
 3   FORMULA-(List Price*RO*(RA^Y))       Y= Age Years
 4
 5   RO VALUES-.60 for tractors,.67 for combines,.56 for others
 6
 7   RA VALUES-.935 for tractors,.92 for combines,.90 for others
 8
 9   NAME OF MACHINE    TRACTOR
10
11    LIST PRICE          $36,000
12    ACTUAL COST         $36,000
13    VALUE  FOR RO           0.60
14    VALUE FOR RA           0.935
16         age,Years      Remaining Val.        Total Deprec.
17
18             1            $20,196               $15,804
19             2            $18,883               $17,117
20             3            $17,656               $18.344
21             4            $16,508               $19,492
22             5            $15,435               $20,565
23             6            $14,432               $21,568
24             7            $13,494               $22,506
25             8            $12,617               $23,383
26             9            $11,797               $24,203
27            10            $11,030               $24,970
```

REPAIR COSTS

A spreadsheet is also very useful in estimating repair costs,(Chapter 8) by using the following formulas.

Accumulated repairs=(List price*RC1*((total hours/RC2)^RC3))

Machine	RC1	RC2	RC3
Tractors	.0005679	100	1.6
Crawlers	.0005048	160	1.6
Combines	.0001757	30	1.8
Cotton Harvesters,	.0004732	20	1.6
Corn Heads	.0004732	20	1.6
Planters, Drills	.0004732	10	1.6
Mowers	.004518	10	1.3
Plows, Hay Equipment	.002008	20	1.3
Disks, Field Cult.	.0001631	20	1.8
Other Tillage Equip.	.0001631	20	1.8

The following example shows one way to use a spreadsheet to determine repair costs.

```
      A         B         C         D         E

 1 NAME OF MACHINE                   TRACTOR
 2
 3 ANNUAL HOURS OF USE                   550
 4
 5 LIST PRICE                          36000
 6
 7 REPAIR CONSTANTS-          RC1=  .0005679
 8                            RC2=       100
 9                            RC3=       1.6
10
12              Repair Costs        Cost Per Hour
13
14  Age,Yrs    Total    Annual     Total     Annual
15  -------    -----    ------     -----     ------
16
17     1       $313       $313     $0.57      $0.57
18     2       $948       $635     $0.86      $1.16
19     3     $1,814       $866     $1.10      $1.57
20     4     $2,874     $1,060     $1.31      $1.93
21     5     $4,107     $1,233     $1.49      $2.24
22     6     $5,498     $1,391     $1.67      $2.53
23     7     $7,036     $1,538     $1.83      $2.80
24     8     $8,712     $1,676     $1.98      $3.05
25     9    $10,518     $1,807     $2.12      $3.28
26    10    $12,450     $1,931     $2.26      $3.51
```

Another good use for spreadsheets is to estimate costs for a specific operation. The following example was taken from Chapter 9.

```
      A        B        C         D         E         F         G
 1 TOTAL COSTS FOR SPECIFIC OPERATIONS
 2
 3    EXAMPLE - MOLDBOARD PLOWING
 4
 5        TRACTOR
 6
 7        List price                      $36,000
 8        Size, Max. PTO Hp                   100
 9        Fuel Type                        Diesel
10        Fuel Consumption Factor(Chap. 7)  0.044
11        Fuel Cost/gal                     $1.00
12        Annual Use, Hours                   500
13        Age, Years                            5
14        Fixed Cost + Repairs/$1,000      $0.392
15        (From Table 1, Appendix)
16
17        PLOW
18
19        List Price                       $6,000
20        Size, feet                          7.5
21        Annual Use, Hours                   100
22        Age, Years                           10
23        Fixed Cost + Repairs/$1,000      $1.588
24        (From Table 7, Appendix)
25        Capacity, Acres/Hour               3.0
26
27        COST FOR PLOWING
28
29        Tractor
30
31        Fixed Cost + Repairs             $14.11
32        Fuel & Lube                       $4.84
33
34        Total                            $18.95
35
36        PLOW
37
38        Fixed Cost + Repairs              $9.53
39
40        TOTAL COST FOR PLOWING           $28.48
```

Fixed cost plus repairs for the $36,000 tractor is shown at E31. The formula for this entry is ($36,000/1,000 x $0.392) so the formula for the spreadsheet would be (+E7/1000*E14). A similar procedure was used for the plow. Fuel and lube costs was determined from the information in Chapter 7 or (Max. PTO Hp x Fuel factor x 1.1 x Price/gal). The spreadsheet entry is (+E8*E10*1.1*E11).

Once you have learned how to set up and use formulas in spreadsheets, there is almost no limit to the machinery management information that can be developed for your situation.

Weights and Measures

The following two charts show conversions of weights and measures from **U.S. systems** to **metric** and vice versa. Charts are also provided on general field measurements.

WEIGHTS AND MEASURES—U.S. TO METRIC

U.S. System			Metric Equivalent
LENGTH			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Mile	mi	5280 feet, 320 rods, 1760 yards	1.609 kilometers
Rod	rd	5.50 yards, 16.5 feet	5.029 meters
Yard	yd	3 feet, 36 inches	0.914 meters
Foot	ft. or ′	12 inches, 0.333 yards	30,480 centimeters
Inch	in or ″	0.083 feet, 0.027 yards	2.540 centimeters
AREA			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Square Mile	sq mi or m^2	640 acres, 102,400 square rods	2.590 square kilometers
Acre	a	4840 square yards, 43,560 square feet	0.405 hectares, 4047 square meters
Square Rod	sq rd or rd^2	30.25 square yards, 0.006 acres	25.293 square meters
Square Yard	sq yd or yd^2	1296 square inches, 9 square feet	0.836 square meters
Square Foot	sq ft or ft^2	144 square inches, 0.111 square yards	0.093 square meters
Square Inch	sq in or in^2	0.007 square feet, 0.00077 square yards	6.451 square centimeters
VOLUME			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Cubic Yard	cu yd or yd^3	27 cubic feet, 46,656 cubic inches	0.765 cubic meters
Cubic Foot	cu ft or ft^3	1728 cubic inches, 0.0370 cubic yards	0.028 cubic meters
Cubic Inch	cu in or in^3	0.00058 cubic feet, 0.000021 cubic yards	16.387 cubic centimeters
MASS AND WEIGHT			
Unit	*Abbreviation*	*Equivalents In Other Units*	
Ton	tn (seldom used)		
short ton		20 short hundredweight, 2000 pounds	0.907 metric tons
long ton		20 long hundredweight, 2240 pounds	1.016 metric tons
Hundredweight	cwt		
short hundredweight		100 pounds, 0.05 short tons	45.359 kilograms
long hundredweight		112 pounds, 0.05 long tons	50.802 kilograms
Pound	lb or lb av also #	16 ounces, 7000 grains	0.453 kilograms
Ounce	oz or oz av	16 drams, 437.5 grains	28.349 grams
Dram	dr or dr av	27.343 grains, 0.0625 ounces	1.771 grams
Grain	gr	0.036 drams, 0.002285 ounces	0.0648 grams
CAPACITY			
Unit	*Abbreviation*	*U.S. Liquid Measure*	
Gallon	gal	4 quarts (231 cubic inches)	3.785 liters
Quart	qt	2 pints (57.75 cubic inches)	0.946 liters
Pint	pt	4 gills (28.875 cubic inches)	0.473 liters
Gill	gi	4 fluidounces (7.218 cubic inches)	118.291 milliliters
Fluidounce	fl oz	8 fluidrams (1.804 cubic inches)	29.573 milliliters
Fluidram	fl dr	60 minims (0.225 cubic inches)	3.696 milliliters
Minim	min	1/60 fluidram (0.003759 cubic inches)	0.061610 milliliters
		U.S. Dry Measure	
Bushel	bu	4 pecks (2150.42 cubic inches)	35.238 liters
Peck	pk	8 quarts (537.605 cubic inches)	8.809 liters
Quart	qt	2 pints (67.200 cubic inches)	1.101 liters
Pint	pt	½ quart (33.600 cubic inches)	0.550 liters

WEIGHTS AND MEASURES—METRIC TO U.S.

Metric System			U.S. Equivalent		
LENGTH					
Unit	*Abbreviation*	*Number of Meters*			
Kilometer	km	1,000	0.62 mile		
Hectometer	hm	100	109.36 yards		
Decameter	dkm	10	32.81 feet		
Meter	m	1	39.37 inches		
Decimeter	dm	0.1	3.94 inches		
Centimeter	cm	0.01	0.39 inch		
Millimeter	mm	0.001	0.04 inch		
AREA					
Unit	*Abbreviation*	*Number of Square Meters*			
Square Kilometer	sq km or km^2	1,000,000	0.3861 square mile		
Hectare	ha	10,000	2.47 acres		
Are	a	100	119.60 square yards		
Centare	ca	1	10.76 square feet		
Square Centimeter	sq cm or cm^2	0.0001	0.155 square inch		
VOLUME					
Unit	*Abbreviation*	*Number of Cubic Meters*			
Stere	s	1	1.31 cubic yards		
Decistere	ds	0.10	3.53 cubic feet		
Cubic Centimeter	cu cm or cm^3 also cc	0.000001	0.061 cubic inch		
CAPACITY					
Unit	*Abbreviation*	*Number of Liters*	*Cubic*	*Dry*	*Liquid*
Kiloliter	kl	1,000	1.31 cubic yards		
Hectoliter	hl	100	3.53 cubic feet	2.84 bushels	
Decaliter	dkl	10	0.35 cubic foot	1.14 pecks	2.64 gallons
Liter	l	1	61.02 cubic inches	0.908 quart	1.057 quarts
Deciliter	dl	0.10	6.1 cubic inches	0.18 pint	0.21 pint
Centiliter	cl	0.01	0.6 cubic inch		0.338 fluidounce
Milliliter	ml	0.001	0.06 cubic inch		0.27 fluidram
MASS AND WEIGHT					
Unit	*Abbreviation*	*Number of Grams*			
Metric Ton	MT or t	1,000,000	1.1 tons		
Quintal	q	100,000	220.46 pounds		
Kilogram	kg	1,000	2.2046 pounds		
Hectogram	hg	100	3.527 ounces		
Decagram	dkg	10	0.353 ounce		
Gram	g or gm	1	0.035 ounce		
Decigram	dg	0.10	1.543 grains		
Centigram	cg	0.01	0.154 grain		
Milligram	mg	0.001	0.015 grain		

ACREAGE CHART FOR VARIOUS ROW LENGTHS AND IMPLEMENT WIDTHS

Row Length (Feet)	Width to Equal One Acre (Feet)	Number of Rows to Equal One Acre Row Width, Inches 20	24	28	36	38	40
300	145.2	87.0	72.6	62.2	48.5	45.9	43.5
400	108.9	65.2	55.0	46.7	36.3	34.4	32.6
500	87.1	52.2	43.5	37.4	29.0	27.5	26.1
600	72.6	43.6	36.3	31.1	24.2	23.0	21.8
700	62.2	37.4	31.0	26.6	20.7	19.6	18.7
800	54.5	32.6	27.2	23.4	18.2	17.2	16.3
900	48.4	29.0	24.2	20.7	16.1	15.3	14.5
1000	43.6	26.2	21.8	18.7	14.5	13.8	13.1
1100	39.6	23.8	19.8	17.0	13.2	12.5	11.9
1200	36.3	21.8	18.1	15.5	12.1	11.5	10.9
1300	33.5	20.0	16.7	14.3	11.2	10.6	10.0
1400	31.1	18.6	15.5	13.3	10.4	9.8	9.3
1500	29.0	17.4	14.5	12.4	9.7	9.2	8.7
1600	27.2	16.4	13.6	11.6	9.1	8.6	8.2

Row Length (Feet)	Number of Trips to Equal One Acre Implement Width, Feet 4	5	6	8	10	12	14	16
300	36.3	29.0	24.2	18.2	14.5	12.1	10.4	9.1
400	27.2	21.8	18.2	13.6	10.9	9.1	7.8	6.8
500	21.8	17.4	14.5	10.9	8.7	7.3	6.2	5.4
600	18.2	14.5	12.1	9.1	7.3	6.0	5.2	4.5
700	15.6	12.4	10.4	7.8	6.2	5.2	4.4	3.9
800	13.6	10.9	9.1	6.8	5.5	4.5	3.9	3.4
900	12.1	9.7	8.1	6.1	4.8	4.0	3.5	3.0
1000	10.9	8.7	7.3	5.4	4.4	3.6	3.1	2.7
1100	9.9	7.9	6.6	4.9	4.0	3.3	2.8	2.5
1200	9.1	7.3	6.1	4.5	3.6	3.0	2.6	2.3
1300	8.4	6.7	5.6	4.2	3.4	2.8	2.4	2.1
1400	7.8	6.2	5.2	3.9	3.1	2.6	2.2	1.9
1500	7.2	5.8	4.8	3.6	2.9	2.4	2.1	1.8
1600	6.8	5.4	4.5	3.4	2.7	2.2	1.9	1.7

SEEDS OR PLANTS PER ACRE, THOUSANDS

Row Spacing, Inches	Seed or Plant Spacing, Inches 1	2	4	6	8	10	12	14	16	18	20
20	313.6	156.8	78.4	52.3	39.2	31.4	26.1	22.4	19.6	17.4	15.7
22	285.1	142.6	71.3	47.5	35.6	28.5	23.8	20.4	17.8	15.8	14.3
24	261.4	130.7	65.3	43.6	32.7	26.1	21.8	18.7	16.3	14.5	13.1
26	241.2	120.6	60.3	40.2	30.2	24.1	20.1	17.2	15.1	13.4	12.1
28	224.0	112.0	56.0	37.3	28.0	22.4	18.7	16.0	14.0	12.4	11.2
30	209.1	104.5	52.3	34.8	26.1	20.9	17.4	14.9	13.1	11.6	10.4
32	196.0	98.0	49.0	32.7	24.5	19.6	16.3	14.0	12.2	10.9	9.8
34	184.5	92.2	46.1	30.7	23.1	18.4	15.4	13.2	11.5	10.2	9.2
36	174.2	87.1	43.6	29.0	21.8	17.4	14.5	12.4	10.9	9.7	8.7
38	165.1	82.5	41.3	27.5	20.6	16.5	13.8	11.8	10.3	9.2	8.2
40	156.8	78.4	39.2	26.1	19.6	15.7	13.1	11.2	9.8	8.7	7.8
42	149.3	74.7	37.3	24.9	18.7	14.9	12.4	10.7	9.3	8.3	7.5

DETERMINING HECTARES FOR VARIOUS ROW LENGTHS AND IMPLEMENT WIDTHS

Row Length (Meters)	Width To Equal One Hectare (Meters)	Number of Rows to Equal One Hectare Row Width, Centimeters						
		51	61	71	76	91	97	102
100	100	196.9	164	140.6	131.2	109.4	103.6	98.4
150	67	131.2	109.4	93.7	87.5	73	69.1	65.6
200	50	98.4	82	70.3	65.6	54.7	51.8	49.2
250	40	78.7	65.5	56.2	52.5	43.7	41.4	39.4
300	33.3	65.6	54.7	46.8	43.7	36.5	34.5	32.8
350	28.6	56.2	46.9	40.2	37.5	31.2	29.6	28.1
400	25	49.2	41	35.2	32.8	27.3	26.0	24.6
450	22.2	43.7	36.5	31.2	29.2	24.3	23.0	21.9
500	20	39.4	32.8	28.1	26.2	21.9	20.7	19.7

Row Length (Meters)	Number of Trips to Equal One Hectare Implement Width, Meters								
	1	1.5	2	2.5	3	3.5	4	4.5	5
100	100	66.7	50	40	33.3	28.6	25	22.2	20
150	60.7	44.4	33.3	26.7	22.2	19	16.7	14.8	13.3
200	50	33.3	25	20	16.7	14.3	12.5	11.1	10
250	40	26.7	20	16	13.3	11.4	10	8.9	8
300	33.3	22.2	16.7	13.3	11.1	9.5	8.3	7.4	6.7
350	28.6	19.0	14.3	11.4	9.5	8.2	7.1	6.3	5.7
400	25	16.7	12.5	10	8.3	7.1	6.25	5.6	5
450	22.2	14.8	11.1	8.9	7.4	6.3	5.6	4.9	4.4
500	20	13.3	10	8	6.7	5.7	5	4.4	4

SEEDS OR PLANTS PER HECTARE, THOUSANDS

Row Spacing Centimeters	Seed or Plant Spacing, Centimeters										
	2.5	5	10	15	20	25	30	35	40	45	50
51	787.6	393.8	196.9	131.3	98.5	78.8	65.6	56.3	49.2	43.7	39.4
61	656	328	164	109.4	82	65.6	54.6	46.9	41	36.4	32.8
71	562.4	281.2	140.6	93.8	70.3	56.2	46.8	40.2	35.2	31.2	28.1
76	524.8	262.4	131.2	87.5	65.6	52.5	43.7	37.5	32.8	29.1	26.2
91	437.6	218.8	109.4	73	54.7	43.8	36.4	31.3	27.4	24.3	21.9
97	414.4	207.2	103.6	69.1	51.8	41.4	34.5	29.6	25.9	23	20.7
102	393.6	196.8	98.4	65.6	49.2	39.4	32.8	28.1	24.6	21.8	19.7

Suggested Readings and Index

SUGGESTED READINGS

TEXTS

Conservation Farming; John Deere Service Training, Dept. F, John Deere Rd., Moline, IL. 61265.

Farm Machinery Management Guide (Special Circular 192); Daum, Donald R. and Waters, William K.; College of Agriculture Extension Service, The Pennsylvania State University, University Park, Pennsylvania 16802.

Farm Power and Machinery Management; Hunt, Donnell; Iowa State University Press, Ames, Iowa 50010, 1968.

Fundamentals of Machine Operation: (8 Other Titles in series): Tractors, Tillage, Planting, Crop Chemicals, Hay and Forage Harvesting, Combine Harvesting, Preventive Maintenance, Agricultural Machinery Safety; John Deere Service Training, Dept. F., John Deere Rd., Moline, IL 61265.

Increase Farm Profits Through Better Machinery Selection (Bulletin A-78); Hinz, Walter W. and Stapleton, H.N.; Cooperative Extension Service, College of Agriculture, The University of Arizona, Tucson, Arizona 85717, 1974.

Modern Concepts of Farm Machinery Management; Bowers, Wendell; Stipes Publishing Company, Champaign, Illinois 61820, 1970.

ASAE PAPERS

Copies of the following recent papers on machinery management may be obtained by writing to the American Society of Agricultural Engineers, 2950 Niles Road, St. Joseph, Michigan 49085.

73-146—*Determination of Optimum Machinery For Corn-Soybean Farms;* Burrows, W.C.; and Siemens, J.C.; Technical Center, Deere & Company, Moline, Illinois.

74-1541 — *Machinery Complement Selection Based on Time Constraints;* H.A. Hughes, VPI and J.B. Holtman; Michigan State University.

74-1542—*An Analysis of Alternative Machinery Systems for Wide-Bed, Narrow-Row Cotton;* L.R. Walker, R.L. Parish and J.H. White; University of Arkansas.

74-1543—*Field Machine Index—Its Use and Application;* E. Renoll; Auburn University.

74-1544—*Eight Years of Farm Machinery Cost Monitoring;* D.R. Hunt; University of Illinois.

74-1545 — *Comparing Hay Harvest Machinery by Simulation;* M.B. Cunney, Agricultural Institute, Oak Park, Carlow, Ireland; and K. VonBargen, University of Nebraska.

74-1546—*Regional Economic Implications of Various Intensities of Use of Rice Production Equipment;* V. Cervinka, California Department of Food and Agriculture; and W.J. Chancellor, University of California, Davis, California.

Farm Power and Machinery Management; Hunt, Donnell; Iowa State University Press, Ames, Iowa 50010, 1983.

85-1527 — *A Standard Model for Repair Cost of Agricultural Machinery.* Rotz, C. A.; Agricultural Engineering Department, Michigan State University, East Lansing, Michigan.

Machinery Management Slide Set (FMO-17203S). 35 mm color. Matching set of 160 slides for illustrations in text. John Deere Service Training, Dept. F., John Deere Road, Moline, Illinois 61265.

VISUALS AND FILMS

Machinery Management Slide Set (FMO-17202S). 35 mm color. Matching set of 160 slides for illustrations in FMO *Machinery Management* text. John Deere Service Training, Dept. F., John Deere Road, Moline, Illinois 61265.

TEACHER'S GUIDE AND STUDENT WORKBOOK

Machinery Management Teacher's Guide (FMO-17503T). Activities, exercises and transparency masters based on text. Student Workbook (FMO-17603W). Study questions. John Deere Service Training, Dept. F., John Deere Road, Moline, Illinois 61265.

SOFTWARE

Machinery Management software and other farm and ranch business software. Write for Software Catalog. John Deere Service Training, Dept. F., John Deere Road, Moline, Illinois 61265.

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